METHODS AND APPARATUS FOR FACILITATING LOCATE AND MARKING OPERATIONS

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Field of Classification Search
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See application file for complete search history.

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(74) Attorney, Agent, or Firm — Cooley LLP

ABSTRACT

Methods and apparatus for facilitating locate and/or marking operation by assessing risk associated with the locate and/or marking operation. A communication interface receives a locate request ticket generated by a one-call center. A processor parses the locate request ticket to extract ticket information obtained from the locate request ticket. The processor further performs a statistical analysis of historical information that is selected based on the ticket information and includes historical damage reports for underground facility infrastructure and/or historical records of previously completed locate request tickets. At least one risk designation is assigned to the locate request ticket based on the statistical analysis of the historical information. The risk designation is transmitted or stored to facilitate clearing (Continued)
the locate request ticket and/or dispatching a locate technician to perform the locate and/or marking operation.

28 Claims, 27 Drawing Sheets

Related U.S. Application Data
continuation of application No. 14/075,011, filed on Nov. 8, 2013, now Pat. No. 8,990,100, which is a continuation of application No. 12/572,260, filed on Oct. 1, 2009, now Pat. No. 8,612,271, which is a continuation-in-part of application No. 12/572,202, filed on Oct. 1, 2009, now Pat. No. 9,208,464, and a continuation-in-part of application No. 12/571,356, filed on Sep. 30, 2009, now Pat. No. 9,208,458, application No. 14/815,230, which is a continuation-in-part of application No. 12/493,109, filed on Jun. 26, 2009, now abandoned.


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G06Q 50/08 (2012.01)
E21D 11/00 (2006.01)
H04W 4/10 (2009.01)
H04W 80/04 (2009.01)
E21B 7/04 (2006.01)

(52) U.S. Cl.
P CPC ... G06Q 10/0639 (2013.01); G06Q 10/06395 (2013.01); G06Q 10/06398 (2013.01); G06Q 50/08 (2013.01); H04W 4/10 (2013.01); H04W 80/04 (2013.01)

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FIG. 2
1900 Start

1901 Receive Electronic Information Associated with a Field Service Operation

1903 Analyze Information to Automatically Generate a Quality Assessment of the Field Service Operation

1905 Output an Indication of the Quality of the Field Service Operation

End

FIG. 3
<table>
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<tr>
<th>Timestamp</th>
<th>Facility Type Identifier (Power)</th>
<th>Facility Mark Location (Curb)</th>
<th>Environmental Landmark Identifier</th>
<th>Location Stamp (555 Main St, W077°20.27840)</th>
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**FIG. 6**

Entry Message
Method 1300

Receive Completed Ticket and Collect Associated Information, Which May Include, Originating Ticket Information, VWL Images, Originating Ticket Assessment, Locating Equipment Data, EM Images, Any Other Information, and the Like

Process Contents of Ticket Information and Automatically Assess Quality of Locate Operation

Categorize Quality of Locate Information

APPROVED

Ticket Approval Process is Completed

End

PROMPT

Real-Time Prompt is Routed to Originating Locate Technician

1328

Originating Locate Technician Processes Prompt, Completes Ticket, and Provides Updated Ticket Information

COACH

QC REFERRAL

Ticket is Routed to QC Personnel for Review and a Course of Action is Determined

Coaching Referral Routed to Coaching Personnel

Coaching Personnel Performs Coaching Activity with Locate Technician

Ticket, and Provides Updated Ticket Information

QC Personnel Routes Ticket to QC Technician for Execution

End

QC Technician Completes Ticket and Provides Updated Ticket Information

FIG. 8
FIG. 9A

FIG. 9B
1. Initialize n=0
2. Select point $x_n$ in set X
3. Identify the point $y_e$ in set Y that is closest to point $x_n$
4. Record distance between $x_n$ and $y_e$ in variable $d_n$
5. More points in set X?
   - Yes: $n = n+1$
   - No: End

**FIG. 10**
FIG. 11B
FIG. 12
Excavation Notice

Ticket 2300

Serial Number: [20083771309] [0000] Channel# [12033306] [0313]

Message Type: [NEW] [EXCAVATION] [ROUTINE]

County: [BUCKS] Municipality: [BENSALEM TWP]

Work Site: [100 ST. FRANCIS LN] Nearest Intersection: [SHOKY MOUNTAIN HWY]

Subdivision: [] Site Marked in White: [N]

Location Information:

[MARK PERIMETER OF BUILDING]

[CODE LAT/LONG: ]

Mapped Type: [P] Mapped Lat/Lon: [15.67654227, -63.7508385]


Type of Work: [STIHL CONSIDY] Depth: [16-20 FT]

Extent of Excavation: [30 FT] Method of Excavation: [DRILL, TRENCHER]

Street: [ ] Sidewalk: [ ] Pub Prop: [ ] Pvt Prop: [ ] Other: [ ]

Scheduled Excavation Date: [06-Jun-09] Through: [15-Jan-09] Elg Time: [10:00] Duration: [3 DAYS]

Response Due Date: [05-Jan-09]

Caller: [ANDREW JONES] Phone: [132-690-8274] Ext: [9]

Excavator: [JACK SMITH CONSTRUCTION] Owner/Manager: [B]

Address: [17 WILLOW RD]

City: [PLANTER] State: [PA] Zip: [19045]

Fax: [161-258-3234] Email: [JACKSMITHCONSTRUCTION.COM]

Work Being Done For: [VARIOUS FTP/PW INFRASIDE]

Person to Contact: [ANDREW JONES] Phone: [132-690-8274] Ext: [9]

Next Time to Call: [ANYTIME]


Job Number: [8637020-302]

Remarks:

[ ]

Serial Number: [20083771309] [300]

FIG. 13
Start

Identify Ticket Source

Retrieve Corresponding Parsing Rules

Identify Next Text Block

Extract Information from Text Block

Transform Extracted Information

Populate Parsed Ticket

More Text Blocks?

End

FIG. 15
Lookup Tables 2800

- Complexity Lookup Table 2810
- Duration Lookup Table 2820
- Risk Lookup Table 2830
- Value Lookup Table 2840
- Skill Level Lookup Table 2850

FIG. 18
FIG. 19

Start

Collect Location Information

Select Location Information with Highest Confidence Level

Confidence Level Sufficiently High?

No

Refine Location Information

Yes

End

FIG. 20

One-Call Center Polygon

21000

21105A

Main Street

21105C

21105B
Determine Dig Site Boundaries

Determine Reason for Excavation

Determine Number and Types of Facilities

Determine Scope for Each Facility Type

End

FIG. 21
Duration Assessment Process

21300 Determine Initial Duration Estimate

21304 Determine Applicable Offsets

21306 Determine Applicable Scaling Factors

21308 Apply Offsets and/or Scaling Factors

End

FIG. 23
Start

21402

Determine Risk Score for Each Applicable Facility Type

21404

Sum Risk Scores

21406

Determine Applicable Scaling Factors

21408

Apply Scaling Factors

End

Risk Assessment Process 21400

FIG. 24
Duplicate Ticket?

Per-Ticket Billing?

Value Assessment Process

Set Revenue to Zero

Determine Per-Ticket Revenue

Determine Billing Rate Per Work Unit or Per Hour

Determine Revenue Based on Estimated Scope or Duration

End

FIG. 25
Start

Determine Requirements Based on Facility Types

Determine Requirements Based on Complexity Types

Determine Requirements Based on Risk Assessment

End

FIG. 26
Work order 21700

Work Order

Work Order Id: 28935
Ticket Number: 20092771234-000
Rescheduled Work Begin Date/Time: 04-Jan-2009 9:00AM
Expected Duration: 1 Hour
Due Date: 05-Jan-2009
Type: Utility Locate
Priority: 3-

Dispatch Address:
Address1: 100 ST. FRANCIS LN
Address2:
Address3:
City: Townsend
State: TN
Zip: 3782
Nearby Intersection: CRESTHILL HILL

Excavation Information:
Work Being Done For: VERIZON FTTA AND INFRASOURCE
Project Type:
Type of Work: JACK SMITH CONSTRUCTION CONSTRUCTION
Extent:
Street:
Excavation Information:
Name:
Address:
City:
State:
Zip:
Phone:
Fax:

Site Information:
From Address1: 110 ST FRANCIS LN
To Address1:
From Address2:
To Address2:
From Address3:
To Address3:
City:
State:
Zip:

Locate Instructions:
MARK PERIMETER OF BUILDING

Caller Information:
Name:
Contact:
Phone:
Ext:
Best Time to Call:

Remarks:

Work Order Task

0201 Utility Locate Gas
0202 Utility Locate Electric
0203 Utility Locate CATV

FIG. 27
METHODS AND APPARATUS FOR FACILITATING LOCATE AND MARKING OPERATIONS

CROSS-REFERENCES TO RELATED APPLICATIONS


Each of the above-identified applications is incorporated by reference herein in its entirety.

BACKGROUND

Field service operations may be any operation in which companies dispatch technicians and/or other staff to perform certain activities, for example, installations, services and/or repairs. Field service operations may exist in various industries, examples of which include, but are not limited to, network installations, utility installations, security systems, construction, medical equipment, heating, ventilating and air conditioning (HVAC) and the like.

An example of a field service operation in the construction industry is a so-called “locate and marking operation,” also commonly referred to more simply as a “locate operation” (or sometimes merely as “a locate”). In a typical locate operation, a locate technician visits a work site in which there is a plan to disturb the ground (e.g., excavate, dig one or more holes and/or trenches, bore, etc.) so as to determine a presence or an absence of one or more underground facilities (such as various types of utility cables and pipes) in a dig area to be excavated or disturbed at the work site. In some instances, a locate operation may be requested for a “design” project, in which there may be no immediate plan to excavate or otherwise disturb the ground, but nonetheless information about a presence or absence of one or more underground facilities at a work site may be valuable to inform a planning, permitting and/or engineering design phase of a future construction project.

In many states, an excavator who plans to disturb ground at a work site is required by law to notify any potentially affected underground facility owners prior to undertaking an excavation activity. Advanced notice of excavation activities may be provided by an excavator (or another party) by contacting a “one-call center.” One-call centers typically are operated by a consortium of underground facility owners for the purposes of receiving excavation notices and in turn notifying facility owners and/or their agents of a plan to excavate. As part of an advanced notification, excavators typically provide to the one-call center various information relating to the planned activity, including a location (e.g., address) of the work site and a description of the dig area to be excavated or otherwise disturbed at the work site.

FIG. 1 illustrates an example in which a locate operation is initiated as a result of an excavator providing an excavation notice to a one-call center. An excavation notice also is commonly referred to as a “locate request,” and may be provided by the excavator to the one-call center via an electronic mail message, information entry via a website maintained by the one-call center, or a telephone conversation between the excavator and a human operator at the one-call center. The locate request may include an address or some other location-related information describing the geographic location of a work site at which the excavation is to be performed, as well as a description of the dig area (e.g., a text description), such as its location relative to certain landmarks and/or its approximate dimensions, within which there is a plan to disturb the ground at the work site. One-call centers similarly may receive locate requests for design projects (for which, as discussed above, there may be no immediate plan to excavate or otherwise disturb the ground).

Using the information provided in a locate request for planned excavation or design projects, the one-call center identifies certain underground facilities that may be present at the indicated work site. For this purpose, many one-call centers typically maintain a collection “polygon maps” which indicate, within a given geographic area over which the one-call center has jurisdiction, generally where underground facilities may be found relative to some geographic reference frame or coordinate system.

Polygon maps typically are provided to the one-call centers by underground facilities owners within the jurisdiction of the one call center (“members” of the one-call center). A one-call center first provides the facility owner/member with one or more maps (e.g., street or property maps) within the jurisdiction, on which are superimposed some type of grid or coordinate system employed by the one-call center as a geographic frame of reference. Using the maps provided by the one-call center, the respective facilities owners/members draw one or more polygons on each map to indicate an area within which their facilities generally are disposed underground (without indicating the facilities themselves). These polygons themselves do not precisely indicate geographic locations of respective underground facilities; rather, the area enclosed by a given polygon generally provides an over-inclusive indication of where a given facilities owner’s underground facilities are
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Different facilities owners/members may draw polygons of different sizes around areas including their underground facilities, and in some instances such polygons can cover appreciably large geographic regions (e.g., an entire subdivision of a residential area), which may further obfuscate the actual/precise location of respective underground facilities.

Based on the polygon maps collected from the facilities owners/members, the one-call center may in some instances create composite polygon maps to show polygons of multiple different members on a single map. Whether using a single member or composite polygon maps, the one-call center examines the address or location information provided in the locate request and identifies a significant buffer zone around an identified work site so as to make an over-inclusive identification of facilities owners/members that may have underground facilities present (e.g., to err on the side of caution). In particular, based on this generally over-inclusive buffer zone around the identified work site (and in some instances significantly over-inclusive buffer zone), the one-call center consults the polygon maps to identify which member polygons intersect with all or a portion of the buffer zone so as to notify these underground facility owners/members and/or their agents of the proposed excavation or design project. Again, it should be appreciated that the buffer zones around an indicated work site utilized by one-call centers for this purpose typically embrace a geographic area that includes but goes well beyond the actual work site, and in many cases the geographic area enclosed by a buffer zone is significantly larger than the actual dig area in which excavation or other similar activities are planned. Similarly, as noted above, the area enclosed by a given member polygon generally does not provide a precise indication of where one or more underground facilities may in fact be found.

In some instances, one-call centers may also or alternatively have access to various existing maps of underground facilities in their jurisdiction, referred to as “facilities maps.” Facilities maps typically are maintained by facilities owners/members within the jurisdiction and show, for respective different utility types, where underground facilities purportedly may be found relative to some geographic reference frame or coordinate system (e.g., a grid, a street or property map, GPS latitude and longitude coordinates, etc.). Facilities maps generally provide somewhat more detail than polygon maps provided by facilities owners/members; however, in some instances the information contained in facilities maps may not be accurate and/or complete. For at least this reason, whether using polygon maps or facilities maps, as noted above the one-call center utilizes a significant buffer zone around an identified work site so as to make an over-inclusive identification of facilities owners/members that may have underground facilities present.

Once facilities implicated by the locate request are identified by a one-call center (e.g., via the polygon map/buffer zone process), the one-call center generates a “locate request ticket” (also known as a “locate ticket,” or simply a “ticket”). The locate request ticket essentially constitutes an instruction to inspect a work site and typically identifies the work site of the proposed excavation or design and a description of the dig area, typically lists on the ticket all of the underground facilities that may be present at the work site (e.g., by providing a member code for the facility owner whose polygon falls within a given buffer zone), and may also include various other information relevant to the proposed excavation or design (e.g., the name of the excavation company, a name of a property owner or party contracting the excavation company to perform the excavation, etc.). The one-call center sends the ticket to one or more underground facility owners and/or one or more locate service providers (who may be acting as contracted agents of the facility owners) so that they can conduct a locate and marking operation to verify a presence or absence of the underground facilities in the dig area. For example, in some instances, a given underground facility owner may operate its own fleet of locate technicians (e.g., locate technician 145), in which case the one-call center may send the ticket to the underground facility owner. In other instances, a given facility owner may contract with a locate service provider to receive locate request tickets and perform a locate and marking operation in response to received tickets on their behalf.

Upon receiving the locate ticket, a locate service provider or a facility owner (hereafter referred to as a “ticket recipient”) may dispatch a locate technician to the work site of planned excavation to determine a presence or absence of one or more underground facilities in the dig area to be excavated or otherwise disturbed. A typical first step for the locate technician includes utilizing an underground facility “locate device,” which is an instrument or set of instruments (also referred to commonly as a “locate set”) for detecting facilities that are concealed in some manner, such as cables and pipes that are located underground. The locate device is employed by the technician to verify the presence or absence of underground facilities indicated in the locate request ticket as potentially present in the dig area (e.g., via the facility owner member codes listed in the ticket). This process is often referred to as a “locate operation.”

In one example of a locate operation, an underground facility locate device is used to detect electromagnetic fields that are generated by an applied signal provided along a length of a target facility to be identified. In this example, a locate device may include both a signal transmitter to provide the applied signal (e.g., which is coupled by the locate technician to a tracer wire disposed along a length of a facility), and a signal receiver which is generally a hand-held apparatus carried by the locate technician as the technician walks around the dig area to search for underground facilities. The transmitter is connected via a connection point to a target object (in this example, underground facility) located in the ground, and generates the applied signal coupled to the underground facility via the connection point (e.g., to a tracer wire along the facility), resulting in the generation of a magnetic field. The magnetic field in turn is detected by the locate receiver, which itself may include one or more detection antennas. The locate receiver indicates a presence of a facility when it detects electromagnetic fields arising from the applied signal. Conversely, the absence of a signal detected by the locate receiver generally indicates the absence of the target facility.

In yet another example, a locate device employed for a locate operation may include a single instrument, similar in some respects to a conventional metal detector. In particular, such an instrument may include an oscillator to generate an alternating current that passes through a coil, which in turn produces a first magnetic field. If a piece of electrically conductive metal is in close proximity to the coil (e.g., if an underground facility having a metal component is below/near the coil of the instrument), eddy currents are induced in the metal and the metal produces its own magnetic field, which in turn affects the first magnetic field. The instrument may include a second coil to measure changes to the first magnetic field, thereby facilitating detection of metallic objects.
In addition to the locate operation, the locate technician also generally performs a “marking operation,” in which the technician marks the presence (and in some cases the absence) of a given underground facility in the dig area based on the various signals detected (or not detected) during the locate operation. For this purpose, the locate technician conventionally utilizes a “marking device” to dispense a marking material on, for example, the ground, pavement, or other surface along a detected underground facility. Marking material may be any material, substance, compound, and/or element, used or which may be used separately or in combination to mark, signify, and/or indicate. Examples of marking materials may include, but are not limited to, paint, chalk, dye, and/or iron. Marking devices, such as paint marking wands and/or paint marking wheels, provide a convenient method of dispensing marking materials onto surfaces, such as onto the surface of the ground or pavement.

In some environments, arrows, flags, darts, or other types of physical marks may be used to mark the presence or absence of an underground facility in a dig area, in addition to or as an alternative to a material applied to the ground (such as paint, chalk, dye, tape) along the path of a detected utility. The marks resulting from any of a wide variety of materials and/or objects used to indicate a presence or absence of underground facilities generally are referred to as “locate marks.” Often, different color materials and/or physical objects may be used for locate marks, wherein different colors correspond to different utility types. For example, the American Public Works Association (APWA) has established a standardized color-coding system for utility identification for use by public agencies, utilities, contractors, and various groups involved in ground excavation (e.g., red—electric power lines and cables; blue—potable water; orange—telecommunication lines; yellow—gas, oil, steam). In some cases, the technician also may provide one or more marks to indicate that no facility was found in the dig area (sometimes referred to as a “clear”).

As mentioned above, the foregoing activity of identifying and marking a presence or absence of one or more underground facilities generally is referred to for completeness as a “locate and marking operation.” However, in light of common parlance adopted in the construction industry, and/or for the sake of brevity, one or both of the respective locate and marking functions may be referred to in some instances simply as a “locate operation” or a “locate” (i.e., without making any specific reference to the marking function). Accordingly, it should be appreciated that any reference in the relevant arts to the task of a locate technician simply as a “locate operation” or a “locate” does not necessarily exclude the marking portion of the overall process. At the same time, in some contexts a locate operation is identified separately from a marking operation, wherein the former relates more specifically to detection-related activities and the latter relates more specifically to marking-related activities.

Inaccurate locating and/or marking of underground facilities can result in physical damage to the facilities, property damage, and/or personal injury during the excavation process that, in turn, can expose a facility owner or contractor to significant legal liability. When underground facilities are damaged and/or when property damage or personal injury results from damaging an underground facility during an excavation, the excavator may assert that the facility was not accurately located and/or marked by a locate technician, while the locate contractor who dispatched the technician may in turn assert that the facility was indeed properly located and marked. Proving whether the underground facility was properly located and marked can be difficult after the excavation (or after some damage, e.g., a gas explosion), because in many cases the physical locate marks (e.g., the marking material or other physical marks used to mark the facility on the surface of the dig area) will have been disturbed or destroyed during the excavation process (and/or damage resulting from excavation).

**SUMMARY**

As discussed above, in various field service operations, a number of field technicians typically are dispatched to perform field operations at any given time, and over any given time period each technician may be assigned numerous work orders, or “tickets” specifying aspects of the field operations to be performed. The volume of tickets per technician may be particularly high in the construction industry, especially in connection with locate and marking operations. The inventors have recognized and appreciated that implementing and performing meaningful oversight and quality control activities in a timely fashion for several field technicians each performing several field operations in a given time period may present challenges, and that failure to perform meaningful oversight and quality control activities may adversely affect customer satisfaction.

Additionally, the inventors have appreciated that the time, effort, and cost that is associated with re-performing work in the field, or with correcting and/or improving poorly performed field calls, may be unacceptable. Consequently, the inventors have realized that a need exists for methods of providing oversight and quality control in field service operations in order to improve customer satisfaction, to identify and reduce the number of poorly performed tickets, and to improve visibility into distributed workforce operations.

In view of the foregoing, various inventive embodiments disclosed herein relate generally to methods, apparatus and systems for computer-aided determination of quality assessment for locate and marking operations. In some embodiments, a quality assessment decision is solely under the discretion of a human reviewer, albeit facilitated in some respects by computer-aided display of information, and electronic record-keeping and communication functions associated with the quality assessment result(s). In other embodiments, information related to a locate and marking operation is electronically analyzed such that a quality assessment is not based solely on human discretion, but rather based at least in part on some predetermined criteria and/or metrics that facilitate an automated determination of quality assessment.

More specifically, in some embodiments, methods, apparatus and systems according to the present disclosure relate to at least partially automating oversight and quality assessment in underground facility locate applications and/or other field service operations. For example, in some embodiments, an automated quality assessment system may receive information related to a locate and marking operation from one or more sources of electronic data (also referred to herein as “field information” or “field data”), analyze the contents of the received electronic data, and automatically assess the quality of the operation based at least in part on the analysis. In other embodiments, automated analysis of at least some of the received electronic data relating to the locate and marking operation facilitates further analysis and/or quality assessment by a human, in which the quality assessment is
not based solely on the discretion of the human, but is significantly informed in some manner by automated analysis of data.

In some exemplary implementations in which a quality of a locate and marking operation is assessed via an at least partially automated process, some or all of the available field information (e.g., which in some instances is derived from data contained in an electronic record of the locate and marking operation) is compared to “reference information” or “reference data” (which in some instances is derived from data contained in a “reference” electronic record). Examples of types of reference information/data used in a quality assessment process according to various embodiments discussed herein may include, but are not limited to: 1) information/data derived from or relating to one or more facilities maps that illustrate the presumed locations of underground facilities purportedly present in a geographic area proximate to or surrounding and subsuming the work site; 2) information/data derived from or relating to one or more previous locate and marking operations at or near the work site (referred to herein as “historical tickets” or “historical data”); and/or 3) information/data relating to one or more environmental landmarks present in a geographic area proximate or surrounding the dig area (e.g., the work site and its environs), or within the dig area itself (referred to herein as “landmark information,” which may be available, for example, from facilities maps, historical tickets, and/or field data collected at or around the time of the locate and marking operation being assessed).

In other aspects, the quality assessment of the locate and/or marking operation may be performed, in whole or in part, by one or more analysis components (e.g., one or more processors executing instructions) separate and/or remote from the locate and/or marking device used in connection with the locate and/or marking operation. Alternatively, the assessment may be performed, in whole or in part, by one or more analysis components incorporated within or otherwise coupled to a locate device, a marking device, and/or a combined locate and marking device. Depending on the nature of the assessment, it may be performed substantially in real time with respect to the generation of field information/data used in connection with the assessment (e.g., one or more of locate information, marking information and landmark information contained in electronic records of a locate and marking operation and/or an electronic manifest of same), otherwise during a locate and/or marking operation, or after completion of a locate and/or marking operation.

In some embodiments described herein, a notification may be generated based on the quality assessment performed. The notification may provide one or more indications of the quality of the locate and marking operation as a whole, or of some aspect thereof. For example, the notification may provide an indication of a degree of correspondence or discrepancy between field data contained in the electronic record of the locate and marking operation and reference data contained in the reference electronic record to which it is compared. Likewise, the notification may provide an indication that the locate and marking operation is or is not approved based on the comparison of the field data to the reference data. The notification may be transmitted electronically or otherwise conveyed, for example, to one or more parties associated with one or more underground facilities within the dig area or in a geographic area proximate to or surrounding and subsuming the work site, one or more parties associated with the performance or oversight of the locate and marking operation, and/or one or more parties associated with excavation of the dig area, for example.

In exemplary embodiments in which the reference information comprises data relating to one or more environmental landmarks (“landmark information,” for example, geographic information and/or landmark category/type information relating to one or more environmental landmarks), a variety of assessments are possible. For example, in a first embodiment relating to environmental landmarks, field information including geographic information, facility type information, and/or other information relating to an underground facility identified and/or marked during a locate and/or marking operation may be compared to reference information comprising landmark information to determine whether or not the location and/or type of one or more facilities identified and/or marked during the locate and/or marking operation are expected in view of the location and/or type of one or more environmental landmarks. Such a comparison may include identifying at least one correspondence or discrepancy between the compared data based on one or more criteria. The landmark information may be derived, for example, from one or more facilities maps, one or more historical tickets, or may be collected together with (e.g., essentially concurrently with) various information relating to the locate and/or marking operation (the locate and/or marking operation to be assessed may include acquisition of landmark information relating to one or more environmental landmarks, and this landmark information may be used for the assessment).

In a second exemplary embodiment relating to environmental landmarks, “new” landmark information collected as part of a current/recent locate and/or marking operation (e.g., via a suitably configured marking device, locate device, or combined locate and marking device, and/or indicated on an electronic manifest for the locate and/or marking operation) may be compared to “reference” landmark information. The reference landmark information may be derived, for example, from one or more facilities maps or one or more historical tickets (which themselves may include previous electronic manifests), and such a comparison may serve as a basis for assessment. In one aspect of this embodiment, both “new” landmark information and other information relating to the locate and/or marking operation (e.g., geographic information, facility type information, etc.) may be compared to the reference landmark information and other facility-related information derived from one or more facilities maps or one or more historical tickets, such that an assessment is based both on a comparison of environmental landmarks and facilities.

In yet another embodiment, a first electronic representation of field information relating to a locate and marking operation (e.g., data in an electronic record, an electronic manifest, etc.), as well as a second electronic representation of reference information (e.g., data in a reference electronic record from any of a variety of sources) to which the first electronic representation is compared, may be visually rendered (e.g., via a computer-generated visual representation in a display field) such that the electronic representations are overlaid to provide a visual aid to an automated assessment process.

In sum, one embodiment of the present invention is directed to a method, performed in a computer comprising at least one hardware processor, at least one tangible storage medium, and at least one input/output (I/O) interface, for evaluating a quality of a locate and/or marking operation to identify a presence or an absence of at least one underground facility at a work site. The method comprises: A) comparing
first information relating to the locate and/or marking operation to second information relating to a presence or an absence of one or more reference environmental landmarks; B) automatically generating, based on A), at least one indication of a quality assessment of the locate and/or marking operation; and C) electronically storing on the at least one tangible storage medium, and/or electronically transmitting via the at least one I/O interface, the at least one indication of the quality assessment so as to provide an electronic record of the quality assessment.

Another embodiment is directed to an apparatus for evaluating a quality of a locate and/or marking operation to identify a presence or an absence of at least one underground facility at a work site. The apparatus comprises: at least one input/output (I/O) interface; at least one memory storing processor-executable instructions; and a processor coupled to the memory and the at least one I/O interface. Upon execution of the processor-executable instructions by the processor, the processor: A) compares first information relating to the locate and/or marking operation to second information relating to a presence or an absence of one or more reference environmental landmarks; B) automatically generates, based on A), at least one indication of a quality assessment of the locate and/or marking operation; and C) controls the at least one memory so as to electronically store, and/or controls the at least one I/O interface so as to electronically transmit, the at least one indication of the quality assessment so as to provide an electronic record of the quality assessment.

Another embodiment is directed to at least one computer-readable storage medium encoded with instructions that, when executed by a processor in a computer comprising at least one input/output (I/O) interface, perform a method for evaluating a quality of a locate and/or marking operation to identify a presence or an absence of at least one underground facility within a work site. The method comprises: A) comparing first information relating to the locate and/or marking operation to second information relating to a presence or an absence of one or more reference environmental landmarks; B) automatically generating, based on A), at least one indication of a quality assessment of the locate and marking operation; and C) electronically storing on the at least one computer-readable storage medium, and/or electronically transmitting via the at least one I/O interface, the at least one indication of the quality assessment so as to provide an electronic record of the quality assessment.

For purposes of the present disclosure, the term “dig area” refers to a specified area of a work site within which there is a plan to disturb the ground (e.g., excavate, dig holes and/or trenches, bore, etc.), and beyond which there is no plan to excavate in the immediate surroundings. Thus, the limits and bounds of a dig area are intended to provide specificity as to where some disturbance to the ground is planned at a given work site. It should be appreciated that a given work site may include multiple dig areas.

The term “facility” refers to one or more lines, cables, fibers, conduits, transmitters, receivers, or other physical objects or structures capable of or used for carrying, transmitting, receiving, storing, and providing utilities, energy, data, substances, and/or services, and/or any combination thereof. The term “underground facility” means any facility beneath the surface of the ground. Examples of facilities include, but are not limited to, oil, gas, water, sewer, power, telephone, data transmission, cable television (TV), and/or internet services.

The term “locate device” refers to any apparatus and/or device, used alone or in combination with any other device, for detecting and/or inferring the presence or absence of any facility, including without limitation, any underground facility. In various examples, a locate device often includes both a locate transmitter and a locate receiver (which in some instances may also be referred to collectively as a “locate instrument set,” or simply “locate set”).

The term “marking device” refers to any apparatus, mechanism, or other device that employs a marking dispenser for causing a marking material and/or marking object to be dispensed, or any apparatus, mechanism, or other device for electronically indicating (e.g., logging in memory) a location, such as a location of an underground facility. Additionally, the term “marking dispenser” refers to any apparatus, mechanism, or other device for dispensing and/or otherwise using, separately or in combination, a marking material and/or a marking object. An example of a marking dispenser may include, but is not limited to, a pressurized can of marking paint. The term “marking material” means any material, substance, compound, and/or element, used or which may be used separately or in combination to mark, signify, and/or indicate. Examples of marking materials may include, but are not limited to, paint, chalk, dye, and/or iron. The term “marking object” means any object and/or objects used or which may be used separately or in combination to mark, signify, and/or indicate. Examples of marking objects may include, but are not limited to, a flag, a dart, and arrow, and/or an RFID marking ball. It is contemplated that marking material may include marking objects. It is further contemplated that the terms “marking materials” or “marking objects” may be used interchangeably in accordance with the present disclosure.

The term “locate mark” means any mark, sign, and/or object employed to indicate the presence or absence of any underground facility. Examples of locate marks may include, but are not limited to, marks made with marking materials, marking objects, global positioning or other information, and/or any other means. Locate marks may be represented in any form including, without limitation, physical, visible, electronic, and/or any combination thereof.

The terms “actuate” or “trigger” (verb form) are used interchangeably to refer to starting or causing any device, program, system, and/or any combination thereof to work, operate, and/or function in response to some type of signal or stimulus. Examples of actuation signals or stimuli may include, but are not limited to, any local or remote, physical, audible, inaudible, visual, non-visual, electronic, mechanical, electromechanical, biomechanical, biosensing or other signal, indication, or event. The terms “actuator” or “trigger” (noun form) are used interchangeably to refer to any method or device used to generate one or more signals or stimuli to cause or causing actuation. Examples of an actuator/trigger may include, but are not limited to, any form or combination of a lever, switch, program, processor, screen, microphone for capturing audible commands, and/or other device or method. An actuator/trigger may also include, but is not limited to, a device, software, or program that responds to any movement and/or condition of a user, such as, but not limited to, eye movement, brain activity, heart rate, other data, and/or the like, and generates one or more signals or stimuli in response thereto. In the case of a marking device or other marking mechanism (e.g., to physically or electronically mark a facility or other feature), actuation may cause marking material to be dispensed, as well as various data relating to the marking operation (e.g., geographic location, time stamps, characteristics of material dispensed, etc.) to be logged in an electronic file stored in memory. In the case of a locate device or other locate
mechanism (e.g., to physically locate a facility or other feature), actuation may cause a detected signal strength, signal frequency, depth, or other information relating to the locate operation to be logged in an electronic file stored in memory.

The terms “locate and marking operation,” “locate operation,” and “locate” generally are used interchangeably and refer to any activity to detect, infer, and/or mark the presence or absence of an underground facility. In some contexts, the term “locate operation” is used to more specifically refer to detection of one or more underground facilities, and the term “marking operation” is used to more specifically refer to using a marking material and/or one or more marking objects to mark a presence or an absence of one or more underground facilities. The term “locate technician” refers to an individual performing a locate operation. A locate and marking operation often is specified in connection with a dig area, at least a portion of which may be excavated or otherwise disturbed during excavation activities.

The term “user” refers to an individual utilizing a locate device and/or a marking device and may include, but is not limited to, land surveyors, locate technicians, and support personnel.

The terms “locate request” and “excavation notice” are used interchangeably to refer to any communication to request a locate and marking operation. The term “locate request ticket” (or simply “ticket”) refers to any communication or instruction to perform a locate operation. A ticket might specify, for example, the address or description of a dig area to be marked, the day and/or time that the dig area is to be marked, and/or whether the user is to mark the excavation area for certain gas, water, sewer, power, telephone, cable television, and/or some other underground facility. The term “historical ticket” refers to past tickets that have been completed.

The term “complex event processing (CEP)” refers to a software and/or hardware-implemented (e.g., facilitated by a computer system, distributed computer system, computer hardware analysis coded in software and/or a combination thereof) technique relating to recognizing one or more events, patterns of events, or the absence of an event or pattern of events, within one or more input streams of information and performing one or more actions and/or computations in response to such recognition, in accordance with specified rules, criteria, algorithms, or logic. CEP generally involves detection of relationships between information contained in input streams (which input streams may include indications of previously recognized events), such as causality, membership, timing, event-driven processes, detection of complex patterns of one or more events, event streams processing, event correlation and abstraction, and/or event hierarchies. CEP may complement and contribute to technologies such as, but not limited to, service oriented architecture (SOA), event driven architecture (EDA), and/or business process management (BPM). CEP allows the information contained in the events flowing through all of the layers of a service business, an enterprise information technology infrastructure and/or management operation to be discovered, analyzed, and understood in terms of its impact on management goals and business processes, and acted upon in real time or as a management process.

The following U.S. published applications are hereby incorporated herein by reference:

It should be appreciated that all combinations of the foregoing concepts and additional concepts discussed in greater detail below (provided such concepts are not mutually inconsistent) are contemplated as being part of the inventive subject matter disclosed herein. In particular, all combinations of claimed subject matter appearing at the end of this disclosure are contemplated as being part of the inventive subject matter disclosed herein. It should also be appreciated that terminology explicitly employed herein that also may appear in any disclosure incorporated by reference should be accorded a meaning most consistent with the particular concepts disclosed herein.

BRIEF DESCRIPTION OF THE DRAWINGS

The drawings are not necessarily to scale, emphasis instead generally being placed upon illustrating the principles of the invention.

FIG. 1 shows an example in which a locate and marking operation is initiated as a result of an excavator providing an excavation notice to a one-call center.

FIG. 2 illustrates a block diagram of an automated quality assessment system for assessing the quality of a field service operation, in accordance with some embodiments of the present disclosure.

FIG. 3 illustrates a flow diagram of an example of a process for automatically assessing the quality of a field service operation, in accordance with some embodiments of the present disclosure.

FIG. 4 illustrates a functional block diagram of an example of an automated quality assessment application for automatically performing quality control in underground facility locate applications, in accordance with some embodiments of the present disclosure.

FIG. 5 illustrates an electronic manifest comprising both image data and non-image data relating to a locate and/or marking operation, in accordance with some embodiments of the present disclosure.

FIG. 6 illustrates a data set that may be associated with an electronic manifest and from which information may be obtained for a quality assessment, in accordance with some embodiments of the present disclosure.

FIG. 7 is an example of a facilities map from which information relating to environmental landmarks may be obtained.

FIG. 8 illustrates a flow diagram of an example of a method of automatically performing quality control in underground facility locate applications using the automated quality assessment system, in accordance with some embodiments of the present disclosure.

FIGS. 9A and 9B illustrate electronic visual renderings of locate and/or marking operations to facilitate an explanation of exemplary concepts relating to assessment based on landmark information, in accordance with some embodiments of the present disclosure.

FIG. 10 illustrates a flow diagram of an example of a process for determining the distance between two sets of geo-location points, in accordance with some embodiments of the present disclosure.

FIG. 11A is an example of a computer-aided visual rendering illustrating an overlay of field data corresponding to a different locate and/or marking operation and reference data, in accordance with some embodiments of the present disclosure.

FIG. 12 shows an example of a ticket management system, according to some embodiments of the present disclosure, comprising a number of software components for performing various functions, such as parsing incoming locate operation tickets, assessing parsed tickets according to appropriate business rules, and scheduling and dispatching locate technicians to perform locate operations.

FIG. 13 shows an example of a locate request ticket that may be received by a ticket management system, according to some embodiments of the present disclosure.

FIG. 14 shows an example of a virtual white lines (VWL) image associated with a ticket received by a ticket management system, according to some embodiments of the present disclosure.

FIG. 15 shows an illustrative process that may be performed by a ticket parsing application to convert an incoming locate request ticket into a parsed ticket, according to some embodiments of the present disclosure.

FIG. 16 shows an example in which a ticket assessment engine accesses one or more stored images that have been processed by a geographic information system, according to some embodiments of the present disclosure.

FIG. 17 shows an example of a facility map with overlaid VWL, according to some embodiments of the present disclosure.

FIG. 18 shows an illustrative set of lookup tables that may be used by a ticket assessment engine, according to some embodiments of the present disclosure.

FIG. 19 shows an illustrative process that may be performed by a ticket assessment engine to select the best available location information and refine the location information when necessary, according to some embodiments of the present disclosure.

FIG. 20 illustrates an exemplary method for refining location information, according to some embodiments of the present disclosure.

FIG. 21 shows an illustrative process that may be performed by a ticket assessment engine to assess the scope of a locate request ticket, according to some embodiments of the present disclosure.

FIG. 22 shows an illustrative process that may be performed by a ticket assessment engine to assess the complexity of a locate request ticket, according to some embodiments of the present disclosure.

FIG. 23 shows an illustrative process that may be performed by a ticket assessment engine to estimate the duration of a locate request ticket, according to some embodiments of the present disclosure.

FIG. 24 shows an illustrative process that may be performed by a ticket assessment engine to compute a risk measurement associated with a locate request ticket, according to some embodiments of the present disclosure.

FIG. 25 shows an illustrative process that may be performed by a ticket assessment engine to compute an estimated value for a locate request ticket, according to some embodiments of the present disclosure.

FIG. 26 shows an illustrative process that may be performed by a ticket assessment engine to specify one or more requirements for selecting a suitable technician to perform a requested locate operation, according to some embodiments of the present disclosure.

FIG. 27 shows an example of a work order that may be created from an incoming locate request ticket, according to some embodiments of the present disclosure.
FIG. 28 shows an illustrative computer that may be used for improving information management, dissemination, and utilization in the locate industry and other field service industries, according to some embodiments of the present disclosure.

DETAILED DESCRIPTION

Following below are more detailed descriptions of various concepts related to, and embodiments of, inventive systems, methods and apparatus for analyzing locate and marking operations with respect to environmental landmarks. It should be appreciated that various concepts introduced above and discussed in greater detail below may be implemented in any of numerous ways, as the disclosed concepts are not limited to any particular manner of implementation. Examples of specific implementations and applications are provided primarily for illustrative purposes.

I. Overview

Various inventive embodiments disclosed herein relate to methods, apparatus and systems for performing oversight and quality control in field service operations, such as locate and marking operations. In general, approvers and/or managers may review the quality of these locate and marking operations in real time and/or within a certain amount of time (e.g., within one day) of completion of the operation. The review of a locate and marking operation by a human (e.g., an approver or manager) and the determination of a quality assessment for the operation based solely on the discretion of the human is referred to herein as a “manual quality assessment.”

Some embodiments described herein are related to methods, apparatus and systems for at least partially automating oversight and quality assessment in underground facility locate operations and/or other field service operations. For example, in some embodiments, an automated quality assessment system may receive “field information” (also referred to as “field data”) related to a locate and marking operation from one or more sources of electronic data (e.g., electronic records of locate and marking operations generated by various locate equipment, an electronic manifest for same, ticket information, service-related information, etc.), electronically analyze the contents of the field information/data by comparing it to “reference information” (also referred to as “reference data”) relating to one or more environmental landmarks (also referred to herein as “landmark information”), and automatically assess the quality of the operation based at least in part on the analysis (e.g., according to predetermined criteria on which the comparison is based and metrics for the criteria).

In other embodiments, automated analysis of field information/data facilitates further analysis and/or quality assessment by a human, in which the quality assessment is not based solely on the discretion of the human, but is significantly informed in some manner by automated analysis of data. As contrasted with the above-discussed “manual quality assessment” of a locate and marking operation by a human, this type of assessment (e.g., based on some degree of electronic analysis of data relating to a locate and/or marking operation) is referred to herein as “automated quality assessment.”

Any suitable number and type of categories may be used, as the invention is not limited in this respect. For example, in some embodiments, a locate operation may be automatically categorized as either, (a) approved—no further action needed; (b) satisfactory, but the locate technician needs coaching or training; (c) unsatisfactory—the ticket needs quality control (QC) action; or (d) real-time prompt—an aspect of the assessment may be suitable for prompting the locate technician in real time with respect to, for example, performing an immediate verification and/or corrective action. In other implementations, a score, grade, or other graduated indication (e.g., based on some maximum range or scale) may be provided as an indication of quality assessment in connection with a locate and marking operation.

II. Automated Quality Assessment

FIG. 2 is a block diagram of an automated quality assessment system 1800. Automated quality assessment system 1800 may be, for example, a computer system having at least one hardware processor 1803, a memory 1805 that comprises at least one tangible storage medium (e.g., RAM, ROM, Flash memory, one or more magnetic storage devices, one or more optical storage devices, or any other type of tangible storage medium), and at least one communications interface 1801. Memory 1805 may store computer-readable (processor-executable) instructions of an automated quality assessment application 1200, which may be executed by processor 1803. When executed by processor 1803, automated quality assessment application 1200 may obtain information associated with a field service operation (e.g., a locate and marking operation) from data sources 1216 via communications interface 1801, analyze the data to assess the quality of the field service operation and may output (e.g., via communication interface 1801) one or more indications of the quality assessment of the field service operation. In some implementations, one or more indications of the quality assessment may be stored in the memory and/or transmitted via the communication interface to provide an electronic record of the quality assessment. The communication interface 1801 may be coupled to a wired or wireless network, bus, or other communication means and may therefore allow the system 1800 to transmit communications to and/or receive communications from other devices.

The computer system of FIG. 2 serving as an automated quality assessment system 1800 may further comprise one or more user interfaces 1802, which may include one or more display units (not shown) The display unit(s) may be provided, for example, to allow a user to view various information in connection with execution of the instructions and/or the indication(s) of quality assessment. In general, the user interface allows a user to communicate with the processor 1803, make manual adjustments, make selections, enter data or various other information, receive information, and/or interact in any of a variety of manners with the processor during execution of the instructions.

FIG. 3 is a flow chart of process 1900 that may be performed by quality assessment application 1200 to automatically assess the quality of a field service operation, such as, for example, a locate and marking operation. Process 1900 begins at act 1901, where the automated quality assessment application receives electronic information associated with a field service operation. The process next continues to act 1903, where the automated quality assessment application analyzes at least some of the received information to automatically generate a quality assessment of the field service operation. The process next continues to
act 1905, where the automated quality assessment application outputs an indication of the quality of the field service operation that is based on the assessment generated in the act 1903.

Referring to FIG. 4, a more detailed block diagram of automated quality assessment application 1200 and data sources 1216 is presented. Automated quality assessment application 1200 may be, for example, a rules-based computer software application that includes, for example, an information processing component 1210, quality assessment outcomes 1212 (e.g., one or more indications of the quality assessment), and a feedback component 1214. Automated quality assessment application 1200 may be fed by any number of data sources 1216, which may include various types of electronic information and/or records of data associated with locate and/or marking operations performed in the field (e.g., both "field information/data" and "reference information/data").

For example, the automated quality assessment application 1200 of the present disclosure may automatically review a variety of field information, which may include "closed" or completed tickets (i.e., tickets pursuant to which a locate and/or marking operation has been performed) and their associated manifests (which may or may not include digital images relating to the locate operation), and/or any information relating thereto, in essentially real time and/or within a specified amount of time, such as within one day, from the ticket being closed. In some embodiments discussed in further detail below, closed tickets may be reviewed by automatically interrogating received data associated with a locate and marking operation against various metrics, such as reference information/data derived from or relating to one or more environmental landmarks.

In some embodiments, information processing component 1210 of automated quality assessment application 1200 may be, for example, a rules-based software component for analyzing the contents of any information that is available in data sources 1216 and then automatically performing an assessment with respect to the quality of a locate operation that is performed in the field. For each locate and marking operation that is assessed, information processing component 1210 may automatically generate a quality assessment outcome 1212 that corresponds to the results of the automatic quality assessment.

Any suitable type of outcome may be generated. For example, in some embodiments, the outcome generated may be a categorization of the locate operation into one of a plurality of quality categories (also referred to herein as "scoring" categories or "grading" categories). For example, based on the automatic quality assessment, a locate operation may be categorized as:

APPROVED—the locate operation is approved, no further action needed;
SATISFACTORY—the locate operation is approved, but the locate technician needs coaching or training;
UNSATISFACTORY—the locate operation is not approved, the ticket needs QC action; or
PROMPT—an aspect of the locate operation assessment may be suitable for transmitting a real-time prompt to the locate technician with respect to, for example, performing a substantially immediate verification and/or corrective action.

Other examples of possible outcomes generated by automated ticket application 1200 include but are not limited to, a numerical score (e.g., a score of 0-100%), a grade (e.g., a grade of A-F), or other graduated indicator, based on some range, scale and/or resolution (granularity), that is indicative of the quality of the assessed locate operation.

Feedback component 1214 of automated quality assessment application 1200 generates the real-time prompts. For example, once the nature of the real-time prompt is determined, feedback component 1214 queries the ticket information in order to ensure that the prompt is directed to the proper originating locate technician. Additional details of the operation of automated quality assessment application 1200 are described with reference to the method of FIG. 6.

III. Exemplary Data Sources for Information Relating to Environmental Landmarks

Examples of data sources 1216 that may be processed by information processing component 1210 of automated quality assessment application 100 may include, but are not limited to, one or more tickets 1220, a virtual white lines (VWL) application 1230, a ticket assessment application 1240, locating equipment data 1250, an electronic manifest (EM) application 1260, one or more facilities maps 1280, an archive of historical tickets 1290, and any other ticketing information and/or records 1295. In implementation, the various data sources 1216 may be supplied by multiple entities (not shown) and accessible to automated quality assessment application 1200 via, for example, a networked computing system for supporting locate operations, an example of which is described with reference to FIGS. 14 and 15.

In various embodiments of automated quality assessment based on information/data derived from the data sources 1216, it should be appreciated that some of this information/data may be treated as "field information/data" and some of this information/data may be treated as "reference information/data" to which the field information/data is compared during the assessment process. Additionally, it should be appreciated that some of the information/data available from the data sources 1216 may be used to "pre-process" or filter one or both of the field information/data and the reference information/data prior to comparison for some types of assessments.

A. Tickets

Tickets 1220 of data sources 1216 are locate request tickets that may be submitted by excavators and processed by one-call centers. Tickets 1220 may include textual ticket information 1222 that comprises instructions with respect to performing a locate operation, such as, but not limited to, a ticket and/or work order number, date information, geographic location information (e.g., address information), excavation information, excavator information, site information (e.g., a description of the dig area, which may include a description of one or more environmental landmarks in or near the dig area/work site), locate operations instructions information, caller information, remarks information, task information, and any combinations thereof.

Historical tickets 1290 of data sources 1216 may include any records of prior locate and/or marking operations performed pursuant to previous locate request tickets. These historical records may relate in some instances, but not necessarily, to locate and/or marking operations performed in the past for the same work site/dig area as specified in the present ticket 1220 subject to quality assessment. In the process of performing the automatic quality assessment of a present ticket 1220, information processing component 1210 may aggregate the information that is contained in one or more historical tickets 1290 (which in some cases may relate to the same work site/dig area) in order to determine the facilities that have been located and/or marked during past locate operations at that site, and/or the presence of one or...
more environmental landmarks. Some of the information types discussed in further detail below may form part of a historical ticket and may be derived from records associated with such tickets for purposes of an assessment. For example, records associated with historical tickets may include digital images having one or more of dig area indicators, electronic locate marks and symbols or icons for environmental landmarks overlaid thereon; additionally, or alternatively, such records may include a variety of data provided by one or more pieces of locating equipment used to perform the locate and/or marking operation (see sections B, C, and D below).

B. Dig Area Indicators and Associated Information

VWL application 1230 of data sources 1216 is a computer software application that provides an electronic drawing tool that may be used by excavators for electronically marking up, for example, a digital aerial image of the dig area. In this manner, instead of (or in addition to) physically visiting the site of the dig area and marking white lines on the ground at that site, an excavator may electronically draw markings (e.g., white lines) on an aerial image of the site, indicating where digging is planned. These marked up digital images may be saved as, for example, VWL images 1232, which may include accompanied with metadata pertaining to various information in the images. One or more VWL images 1232 in turn may be associated with, for example, tickets 1220 and transmitted to locate companies.

VWL application 1230 may be implemented, for example, as described in U.S. patent application Ser. No. 12/366,853 filed Feb. 6, 2009, entitled “Virtual white lines for delimiting planned excavation sites,” U.S. patent application Ser. No. 12/475,906 filed Jun. 1, 2009, entitled “Virtual white lines for delimiting planned excavation sites of staged excavation projects,” U.S. patent application Ser. No. 12/422,364 filed Apr. 13, 2009, entitled “Virtual white lines (VWL) application for indicating a planned excavation or locate path.” Each of these patent applications is hereby incorporated by reference herein in its entirety.

In one example, the dig area indicators in a VWL image may include two-dimensional (2D) drawing shapes, shades, points, symbols, coordinates, data sets, or other indicators to indicate on a digital image the dig area in which excavation is to occur. To generate the electronic image having dig area indicators, an image (e.g., an aerial image) of the work site may be sent to an excavator via a network, the excavator may use a computing device executing the VWL application 1230 to create a VWL image by marking up the image to include one or more dig area indicators precisely delimiting one or more dig areas within the work site and, in response, the marked-up VWL image may be received from the excavator via the network.

As noted above, a VWL image 1232 may include metadata corresponding to any markings or content in the image; in particular, geographic information including geographic coordinates (e.g., latitude and longitude values) for any dig area indicators marked on the image may accompany or be included in an image file as metadata, and these geographic coordinates may be employed in some manner as part of a quality assurance process. For example, as discussed further below, in one embodiment geographic information derived from a virtual white lines (VWL) application 1230 (e.g., geographic coordinates associated with one or more dig area indicators contained in a VWL image 1232) may be used by automated quality assessment application 1200 to filter or limit the contents of either field data or reference data prior to analysis/comparison.

In particular, in one exemplary implementation, geographic coordinates associated with a dig area indicator may be used to select contents that relates only to a geographic area including the geographic coordinates for the dig area indicator, or contents that falls within a predetermined radius of the geographic coordinates for the dig area indicator or a polygon-shaped buffer zone around the geographic coordinates for the dig area indicator. In yet another example, geographic coordinates associated with a dig area indicator may be used to filter out some contents that does not relate to a specifically delimited dig area within a work site as defined by the VWL application (e.g., first geographic information or another portion of information may be selected from the field data, and/or second geographic information or another portion of information may be selected from the reference data, that relates only to a geographic area delimited by the VWL geographic information). Accordingly, it should be appreciated that in some embodiments, the dig area indicator coordinates may identify a plurality of points along a perimeter of the delimited dig area, and these coordinates may be used to select specific geographic information (e.g., filter out geographic information outside of the delimited dig area). In other embodiments, the dig area indicator coordinates may identify a single point, in which case the coordinates may be used to select particular information based at least in part on the coordinates for the single point.

C. Locating Equipment Data

With respect to locating equipment data 1250, as noted above, a locate technician may use locating equipment, such as a locate instrument set (including a locate receiver device), a marking device, or a combined locate and marking device, so as to perform a locate and marking operation. Locating equipment data 1250 of data sources 1216 may be any information that is collected and/or generated (e.g., one or more electronic records) by any type of locating equipment equipped with components that are capable of collecting electronic information and/or creating electronic records about locate and marking operations that are performed in the field. In some examples, locating equipment data 1250 is constituted by “marking information” or marking device data 1252 that is associated generally with the marking functionality of a locate and marking operation, and/or “locate information” or locate receiver data 1254 that is associated generally with the locating/detection functionality of a locate and marking operation. Locating equipment data 1250 also may include “landmark information” that may be acquired by suitably configured locating equipment (e.g., a marking device, a locate device, or a combined locate and marking device capable of operating in a “landmark mode”), which information may be acquired either independently or as part of (e.g., during or proximate in time to) a locate and marking operation.

In one example, marking device data 1252 of locating equipment data 1250 may be electronic information and/or one or more electronic records of data that is provided by electronic marking devices and/or marking systems. Examples of electronic marking devices and/or marking systems that may provide marking device data 1252 may include, but are not limited to, those described in reference to U.S. patent application Ser. No. 11/696,606, filed Apr. 4, 2007 and published Oct. 9, 2008, entitled “Marking system and method,” U.S. patent application Ser. No. 11/685,002, filed Mar. 13, 2007 and published Sep. 18, 2008, entitled “Marking system and method,” U.S. Non-provisional application Ser. No. 12/568,087, filed on September 28, entitled “Methods and Apparatus for Generating an Electronic

Table 1 shows one example of a sample of marking device data 1252 of locating equipment data 1250 that may be captured as the result of, for example, an actuation of a marking device. In some exemplary implementations, an electronic record of a marking operation may include multiple data entries as shown in the example of Table 1 for respective actuations of a marking device to dispense a marking material (e.g., in some cases there may be one set of data as shown in Table 1 for each actuation). In this manner, each time a marker is dispensed (so as to indicate a presence or absence of a given underground facility), data is collected relating to the geographic location of the dispensed marker (e.g., geo-location data). Additionally, data relating to a characteristic of the dispensed marker (e.g., color and/or brand) is included in the data entries of the electronic record, as well as other data germane to the marking operation.

**TABLE 1**

<table>
<thead>
<tr>
<th>Example marking device data 1252 of locating equipment data 1250</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service provider ID 0482</td>
</tr>
<tr>
<td>Locate technician ID 4815</td>
</tr>
<tr>
<td>Marking Device ID 7362</td>
</tr>
<tr>
<td>Timestamp data 12-Jul-2008; 09:35:15.2</td>
</tr>
<tr>
<td>Geo-location data N34°43.57518, W078°49.78314</td>
</tr>
<tr>
<td>Marking material data Color = Red, Brand = ABC</td>
</tr>
<tr>
<td>Temperature data 73 degrees F.</td>
</tr>
<tr>
<td>Humidity data 30%</td>
</tr>
<tr>
<td>Light data 4.3 volts</td>
</tr>
<tr>
<td>Compass data 213 degrees</td>
</tr>
<tr>
<td>Accelerometer data -40</td>
</tr>
<tr>
<td>Battery strength data 0.275 g</td>
</tr>
<tr>
<td>73%</td>
</tr>
</tbody>
</table>

Table 2 below shows another example of marking device data 1252 of locating equipment data 1250 that may be captured as the result of, for example, one or more actuations of a marking device. Specifically, Table 2 illustrates multiple “actuation data sets” of an electronic record of a marking operation as generated by a marking device, in which each actuation data set includes information associated with multiple actuation event entries logged during a corresponding actuation and dispensing of a locate mark. Table 2 shows three actuation data sets of an electronic record, corresponding to three actuations of the marking device (e.g., act-1, act-2, and act-3). As may be appreciated from the information shown in Table 2, multiple pieces of geo-location data are logged for each actuation of a marking device (in addition to various other information).
TABLE 2-continued

| Product data | Color = Red, Brand = ABC; Type/Batch = 224B-1 |
| Locate request data | Requestor: XYZ Construction Company, 222 Main St., Orlando, FL |

With regard to the marking material color information that may be included in marking device data 1252 as exemplified in Tables 1 and 2, Table 3 shows an example of the correlation of marking material color to the type of facility to be marked.

**TABLE 3**

<table>
<thead>
<tr>
<th>Marking material color</th>
<th>Facility Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>Proposed excavation</td>
</tr>
<tr>
<td>Pink</td>
<td>Temporary survey markings</td>
</tr>
<tr>
<td>Red</td>
<td>Electric power lines, cables or conduits, and lighting cables</td>
</tr>
<tr>
<td>Yellow</td>
<td>Gas, oil, steam, petroleum, or other hazardous liquid or gaseous materials</td>
</tr>
<tr>
<td>Orange</td>
<td>Communications, cable TV, alarm or signal lines, cables, or conduits</td>
</tr>
<tr>
<td>Blue</td>
<td>Water, irrigation, and slurry lines</td>
</tr>
<tr>
<td>Purple</td>
<td>Reclaimed water, irrigation and slurry lines</td>
</tr>
<tr>
<td>Green</td>
<td>Sewers, storm sewer facilities, or other drain lines</td>
</tr>
<tr>
<td>Black</td>
<td>Mark-out for errant lines</td>
</tr>
</tbody>
</table>

In another example, locate receiver data 1254 of locating equipment data 1250 may be electronic information (e.g., one or more electronic records) of data that is provided by electronic locate receiver devices and/or systems. Examples of a locate receiver device that may provide locate receiver data 1254 are described in U.S. Non-provisional application Ser. No. 12/569,192, filed on Sep. 29, 2009, entitled “Methods, Apparatus, and Systems for Generating Electronic Records of Locate and Marking Operations, and Combined Locate and Marking Apparatus for Same,” U.S. Provisional Patent Application Ser. No. 61/151,578, entitled “Locating equipment that has enhanced features for increased automation in underground facility locate applications;” and U.S. Provisional Patent Application Ser. No. 61/102,122, filed on Oct. 2, 2008, entitled “Combination Locate and Marking Device With a Data Acquisition System Installed Therin, and Associated Methods,” which applications are both hereby incorporated herein by reference in their entirety.

Table 4 below shows an example of a sample of locate receiver data 1254 of locating equipment data 1250 that may be captured, for example, at one or more times during operation/use of an appropriately configured locate receiver. Different models of locate receivers and transmitters are available from a variety of manufacturers and have different features; accordingly, it should be appreciated that the information content and type provided in Table 4 is exemplary of possible information relating to locate receivers on which a quality assessment of a locate operation may be based, and that other types and values for information are possible. With respect to information potentially provided by a given locate receiver as shown in Table 4 below, the “gain” is typically a measure of the degree of sensitivity of a locate receiver antenna that is picking up a signal emanating from along an underground facility (alternatively, “gain” may be viewed as a degree of amplification being applied to a received signal). Gain may be expressed in terms of any scale (e.g., 0-100), as a numeric value or percentage. “Signal strength” refers to the strength of a received signal at a given gain value; signal strength similarly may be expressed in terms of any scale, as a numeric value or percentage. Generally speaking, higher signal strengths at lower gains typically indicate more reliable information from a locate receiver, but this may not necessarily be the case for all locate operations.

In another example, both marking device data 1252 and locate receiver data 1254 of locating equipment data 1250 may be electronic information (e.g., one or more electronic records) of data that is provided by a combined locate and marking device. An example of such a combined locate and marking device is described in U.S. Non-provisional application Ser. No. 12/569,192, filed on Sep. 29, 2009, entitled “Methods, Apparatus, and Systems for Generating Electronic Records of Locate and Marking Operations, and Combined Locate and Marking Apparatus for Same,” and U.S. Provisional Patent Application Ser. No. 61/102,122, filed on Oct. 2, 2008, entitled “Combination Locate and Marking Device With a Data Acquisition System Installed Therin, and Associated Methods,” which applications are both hereby incorporated herein by reference in their entirety.

Table 5 below illustrates one non-limiting example of four actuation data sets that may be collected in an electronic record generated by a combined locate and marking device.
in which each data set corresponds, for example, to a separate actuation event to dispense marking material. It should be appreciated, however, that these are merely examples, and that various alternative electronic records may be generated according to the aspects of the invention, for example reflecting different types of information associated with operation of a combination locate and marking device.

Each of the four records of Table 5 includes general information not limited to either the locate receiver functionality or marking functionality of the combination device, such as an identification of the service provider (Service provider ID), an identification of the user (User ID), an identification of the device (Device ID), and information about the requestor of the locate operation and the requested address (Locate request data). In addition, an entry describing the mode of data collection (e.g., Manual) for the device is also collected, which may indicate that information is logged into the record(s) upon actuation of the combined locate and marking device. Information about the actuation itself, such as the time of actuation (Timestamp data), actuation duration, and geographical location (geo-location data) at the start, during, and/or at end of the actuation may also be included. The data sets also include information relating to the locate receiver functionality of the combination locate and marking device, including the receiver detection mode (i.e., PEAK in Table 5), the strength of a detected signal, and the frequency of the detected signal. Information relating to a depth measurement (Facility depth) is also included, as is information about the marking material to be dispensed by the combination locate and marking device. Again, it should be appreciated that Table 5 is an illustration of one electronic record including multiple data sets that may be generated in association with operation of a combination locate and marking device, and that other forms of electronic records are also possible.

**TABLE 5**

<table>
<thead>
<tr>
<th>Record</th>
<th>Service provider ID</th>
<th>User ID</th>
<th>Device ID</th>
<th>Device mode</th>
<th>Timestamp data</th>
<th>Actuation duration</th>
<th>Start actuation location data</th>
<th>End actuation location data</th>
<th>Locate mode</th>
<th>Signal strength (% of maximum)</th>
<th>Signal frequency</th>
<th>Facility depth</th>
<th>Marking material data</th>
<th>Locate request data</th>
</tr>
</thead>
<tbody>
<tr>
<td># 1001</td>
<td>4815</td>
<td></td>
<td>7362</td>
<td>MANUAL</td>
<td>12-Jul-2008; 06:35:15</td>
<td>0.5 sec</td>
<td>2650.9348, N, 08003.5057, W</td>
<td>2650.9353, N, 08003.5055, W</td>
<td>Mode = PEAK</td>
<td>85%</td>
<td>1 kHz</td>
<td>3.4 meters</td>
<td>Color = RED, Brand = ABC</td>
<td>Requestor = XYZ</td>
</tr>
</tbody>
</table>

**Electronic Record for Combination Locate and Marking Device**

<table>
<thead>
<tr>
<th>Record</th>
<th>Service provider ID</th>
<th>User ID</th>
<th>Device ID</th>
<th>Device mode</th>
<th>Timestamp data</th>
<th>Actuation duration</th>
<th>Start actuation location data</th>
<th>End actuation location data</th>
<th>Locate mode</th>
<th>Signal strength (% of maximum)</th>
<th>Signal frequency</th>
<th>Facility depth</th>
<th>Marking material data</th>
<th>Locate request data</th>
</tr>
</thead>
<tbody>
<tr>
<td># 1002</td>
<td>4815</td>
<td></td>
<td>7362</td>
<td>MANUAL</td>
<td>12-Jul-2008; 09:35:18</td>
<td>0.4 sec</td>
<td>2650.9256, N, 08003.5234, W</td>
<td>2650.9256, N, 08003.5226, W</td>
<td>Mode = PEAK</td>
<td>85%</td>
<td>1 kHz</td>
<td>3.4 meters</td>
<td>Color = RED, Brand = ABC</td>
<td>Requestor = XYZ</td>
</tr>
</tbody>
</table>

While the collection and logging of locate information and marking information to generate an electronic record is discussed in some aspects, for purposes of illustration, in terms of actuation data sets (i.e., a set of data that is associated and logged with a corresponding actuation of a locate device, marking device, or combined locate and marking device), it should be appreciated that electronic records as discussed herein are not limited in this respect. More generally, an electronic record of a locate and/or marking operation may be generated in any of a variety of manners, have a variety of file formats and/or data structures, and include any of a variety of locate information and/or marking information (some of which may be germane to one or more actuations of a device, some of which
may be common to multiple actuations or the overall locate and/or marking operation in general, and some of which may not be related to specific actuations). For example, in some exemplary implementations electronic records may be a “flat files” including a succession of time stamped “event entries” of various locate information and/or marking information (logged automatically as a result of one or more particular conditions, e.g., exceeded thresholds for various signals, or manually as a result of user actuation of a device), or a differently formatted file (e.g., an ASCII file, an XML file) having a data structure that segregates or separates in some manner the locate information and/or marking information into multiple different fields.

It should also be appreciated that one or both of the marking device data 1252 and locate receiver data 1254 of locating equipment data 1250, received from any of the marking devices, locate devices, or combined locate and marking devices referenced above, may include landmark information (in addition to, or alternatively to, locate information and marking information). Landmark information may include any information relating to one or more environmental landmarks of interest (e.g., in and around the work site/dig area and/or generally in the vicinity of the locate and marking operation). Examples of landmark information include, but are not limited to, geo-location data of an environmental landmark, type of environmental landmark, and a time stamp for any acquired information relating to an environmental landmark. In some instances, landmark information may be acquired from locate equipment particularly configured to operate in a landmark mode so as to acquire such information, as well as one or more other modes (e.g., “locate mode” or “marking mode”) to accomplish functions relating to detection and/or marking of underground facilities.

Tables 6A and 6B below show examples of landmark information that may be included in an electronic record forming part of either marking device data 1252 or locate receiver data 1254 of locating equipment data 1250. Table 6A shows the format and content of an electronic record entry for a utility pole, which includes one geo-location data point, and Table 6B shows the format and content of an electronic record entry for a pedestal, which includes four geo-location data points (i.e., one for each corner of the pedestal). As noted above, it should be appreciated that the format and content shown below in Tables 6A and 6B is provided primarily for purposes of illustration, and that a variety of formats and content may be employed for an electronic record entry for landmark information.

D. Electronic Manifests

Electronic Manifest (EM) application 1260 of data sources 1216 is a computer software application that may be used to create an electronic manifest of a locate and/or marking operation. As discussed above, an electronic manifest may include a digital (e.g., aerial) image of the work site/dig area and its surroundings, upon which may be overlaid any of a variety of information relating to a locate and/or marking operation (e.g., derived from any of the information discussed above in connection with electronic records generated by various locate equipment). In one example of an electronic manifest, one or more “electronic locate marks” are overlaid on a digital image for indicating corresponding physical locate marks that have been placed on the ground, pavement or other surface at the site, thereby indicating the geo-locations and types of facilities present. One or more landmarks also may be indicated on the digital image together with the electronic locate marks. Via the EM application 1260, the digital images may be marked up “manually” by a technician (e.g., using a stylus or other type of user interface in conjunction with the digital image displayed in a display field) to include one or more electronic locate marks and/or one or more identifiers for environmental landmarks. Alternatively, a digital image may be marked up “automatically” by importing data, for example, from one or more pieces of locate equipment (e.g., a locate device, a marking device, or a combined locate and marking device) and overlaying the imported data on the digital image.

In one example, the starting digital images to be marked up using EM application 1260 may be VWL images 1232 that are associated with tickets 1220. In this manner, the resulting EM image may contain the original dig area indicator (e.g., from the VWL image) to indicate or delimit the dig area for the locate and marking operation, together with any electronic locate marks and/or landmarks added to the image via the EM application. The marked up digital images may be saved as, for example, EM images 1262, which may be associated with, for example, tickets 1220 and may be used by locate companies to support proof of work compliance. In some embodiments, EM application 1260 may be implemented as described in U.S. patent application Ser. No. 12/369,232, filed Feb. 11, 2009 entitled “Searchable records of underground facility locate marking operations,” which is incorporated by reference herein in its entirety.

<table>
<thead>
<tr>
<th>TABLE 6A</th>
<th>Example record of landmark information acquired for a utility pole</th>
</tr>
</thead>
<tbody>
<tr>
<td>Record</td>
<td></td>
</tr>
<tr>
<td>Service</td>
<td></td>
</tr>
<tr>
<td>Provider ID</td>
<td></td>
</tr>
<tr>
<td>User ID</td>
<td></td>
</tr>
<tr>
<td>Device ID</td>
<td></td>
</tr>
<tr>
<td>Type of EL</td>
<td></td>
</tr>
<tr>
<td>Timestamp data</td>
<td></td>
</tr>
<tr>
<td>geo-location data</td>
<td></td>
</tr>
<tr>
<td>Locate request data</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TABLE 6B</th>
<th>Example record of landmark information acquired for a pedestal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Record</td>
<td></td>
</tr>
<tr>
<td>Service</td>
<td></td>
</tr>
<tr>
<td>Provider ID</td>
<td></td>
</tr>
<tr>
<td>User ID</td>
<td></td>
</tr>
<tr>
<td>Device ID</td>
<td></td>
</tr>
<tr>
<td>Type of EL</td>
<td></td>
</tr>
<tr>
<td>Timestamp data</td>
<td></td>
</tr>
<tr>
<td>geo-location data</td>
<td></td>
</tr>
<tr>
<td>Locate request data</td>
<td></td>
</tr>
</tbody>
</table>

Requester: XYZ Construction Company, 222 Main St, Orlando, FL.
As noted above in connection with VWL images 1232 provided by VWL application 1230, an EM image 1262 may include metadata corresponding to any markings or content in the image; in particular, geographic coordinates (e.g., latitude and longitude values) for any dig area indicator, electronic locate marks, and/or landmarks marked on the image may accompany or be included in an image file as metadata. Accordingly, these geographic coordinates, as well as any other information provided by EM application, may be employed in some manner as part of a quality assessment process (e.g., as field information/data, or in some instances as reference information/data, or in some instances to pre-process or filter one or both of field information/data and reference information/data prior to comparison).

FIG. 5 shows an example of an electronic manifest 900 that comprises both image data and non-image data. In this example, the electronic manifest 900 comprises a marked-up image 905 showing locate mark indicators 910 (e.g., to indicate locations of physical locate marks), offset indica 915 (e.g., to indicate distances between physical locate marks and certain environmental landmarks) and dig area indicators 920 (e.g., as provided by an excavator on a VWL image). In addition, the electronic manifest 900 comprises non-image information relating to the locate and/or marking operation, such as a ticket number or identifier 925, a name or identifier 930 associated with the locate technician (which may include facility owner/operator, or locate company/technician), a time and date stamp 935 indicating when the electronic manifest was created, a location stamp 940 indicating where the electronic manifest was created, a completed list of markings used in the locate and/or marking operation, and a locate technician signature 950 certifying that the information of the electronic manifest is correct.

Although FIG. 5 shows an example of an electronic manifest including specific types of ticket information, it should be appreciated that an electronic manifest as described herein is not limited in this regard, and may alternatively include other combinations of ticket information. Also, an electronic manifest may be displayed and/or formatted in manners different from the example shown in FIG. 5.

The underlying electronic data used to generate an electronic manifest (e.g., the electronic manifest 900 shown in FIG. 5) may be represented and/or stored in any suitable manner, as the present disclosure is not limited in this respect. In some embodiments, the marked-up image(s) and the non-image information may be stored as a single file. For example, the non-image information may be included as metadata associated with the marked-up image(s). In other embodiments, the marked-up image(s) and the non-image information may be formatted as separate data sets and may be transmitted and/or stored separately. In another aspect, whether transmitted/stored separately or together, the marked-up image(s) and the non-image information may be linked together in some manner as relating to a common electronic record.

FIG. 6 shows an example of a data set 1000 that may be used to generate an electronic manifest. In this example, the data set 1000 may include a timestamp field 1010, a facility type identifier field 1020, a facility mark location field 1030, an environmental landmark identifier field 1040, an environmental landmark location field 1050, an other information field 1060, a facility owner/operator field 1065, a marking method field 1070, a property address field 1080, a ticket number field 1090, a location stamp field 1015, and a certification field 1025.

Although FIG. 6 shows specific examples of information fields, it should be appreciated that the present disclosure is not limited in this regard. In other implementations, the data set 1000 may include additional, fewer, or different fields. Some exemplary information fields are discussed briefly below.

The timestamp field 1010 may include time data that identifies the day and/or time that a locate and/or marking operation is performed. This may coincide with a time at which an environmental landmark location is identified in connection with the dig area. The time data in the timestamp field 1010 is shown in FIG. 10 as 9:43 a.m. on Oct. 20, 2005, although any type of date and/or time code may be used. The information in timestamp field 1010 may be useful in establishing when a locate and/or marking operation occurred.

The facility type identifier field 1020 may include an identifier that identifies a type of underground facility that is being marked. The identifier in the facility type identifier field 1020 is shown in FIG. 10 as “power,” although any type of identifier may be used. The facility mark location field 1030 may include geographical information corresponding to a physical locate mark. In some implementations, the geographical information may identify a set of geographical points along a marking path of a located facility line. The geographical information in the facility mark location field 1030 is shown in FIG. 10 as N38°51.40748, W077°20.27798; . . . ; N38°51.40784, W077°20.27865, although any type of geographical information may be used.

The information in the facility mark location field 1030 may be useful in graphically presenting the facility locate marks on a map, and/or to verify that the locate and/or marking operation was actually and accurately performed. Additionally, or alternatively, the facility mark location field 1030 may include geographical information for multiple facility locate marks.

The environmental landmark identifier field 1040 may include an identifier that identifies a type of environmental landmark being marked. The identifier in the environmental landmark identifier field 1040 is shown in FIG. 10 as “curb,” although any type of identifier may be used. The environmental landmark location field 1050 may include geographical information corresponding to the environmental landmark identified in the environmental landmark identifier field 1040. The geographical information in the environmental landmark location field 1050 is shown in FIG. 10 as N38°51.40756, W077°20.27805; . . . ; N38°51.40773, W077°20.27858, although any type of geographical information may be used.

The other information field 1060 may store any other data that may be useful, including user notes, such as offset or distance information that identifies a distance between one or more environmental landmarks and one or more facility locate marks. The other information field 1060 is shown in FIG. 10 as including “1.2 meters between curb and power line,” although any other data may be used. Additionally, or alternatively, the other information field 1060 may include audio/voice data, transcribed voice-recognition data, or the like to incorporate user notes.

E. Facilities Maps

Facilities maps 1280 of data sources 1216 are any physical, electronic, or other representation of the geographic location, type, number, and/or other attributes of a facility or facilities. Facilities maps 1280 may be supplied by the
various facility owners and may indicate the geographic location of the facility lines (e.g., pipes, cables, and the like) owned and/or operated by the facility owner. For example, facilities maps 1280 may be supplied by the owner of the gas facilities, power facilities, telecommunications facilities, water and sewer facilities, and so on. In the process of performing the automatic quality assessment, information processing component 1210 may aggregate the information that is contained in multiple facilities maps 1280 in order to determine all the facilities that are present in and around a certain work site/dig area.

As indicated above, facilities maps may be provided in any of a variety of different formats. As facilities maps often are provided by facility owners of a given type of facility, typically a set of facilities maps includes a group of maps covering a particular geographic region and directed to showing a particular type of facility disposed/deployed throughout the geographic region. One facilities map of the set of maps is sometimes referred to in the relevant arts as a “plat.”

Perhaps the simplest form of facilities maps is a set of paper maps that cover a particular geographic region. In addition, some facilities maps may be provided in electronic form. An electronic facilities map may in some instances simply be an electronic conversion (i.e., a scan) of a paper facilities map that includes no other information (e.g., electronic information) describing the content of the map, other than what is printed on the paper maps.

Alternatively, however, more sophisticated facilities maps also are available which include a variety of electronic information, including geographic information and other detailed information, regarding the contents of various features included in the maps. In particular, facilities maps may be formatted as geographic information system (GIS) map files, in which map features (e.g., facility lines and other features) are represented as shapes and/or lines, and the file provides metadata describing the geographic locations and types of map features. In some examples, a GIS map file may indicate a facility line using a straight line, and may include some symbol or other annotation (e.g., a diamond shape) at each endpoint of the line to indicate where the line begins and terminates. From the foregoing, it should be appreciated that in some instances, given that the geo-locations of two termination or end-points of a given facility line may be provided by the map, the geo-location of any point on the facility line may be determined from these two end-points.

Examples of a wide variety of environmental landmarks that may be represented in a GIS facilities map file include, but are not limited to: landmarks relating to facilities such as pedestrian boxes, utility poles, fire hydrants, manhole covers and the like; one or more architectural elements (e.g., buildings); and/or one or more traffic infrastructure elements (e.g., streets, intersections, curbs, ramps, bridges, tunnels, etc.). A GIS facilities map file may also include various shapes or symbols indicating different environmental landmarks relating to facilities, architectural elements, and/or traffic infrastructure elements.

Examples of information provided by metadata for the map file (i.e., included as part of the electronic file for the map) include, but are not limited to, information about the geo-location of various points along a given line, the termination points of a given line (e.g., the diamond shapes indicating the start and end of the line), the type of facility line (e.g., facility type and whether the line is a service line or main), geo-location of various shapes and/or symbols for other features represented in the map (environmental landmarks relating to facilities, architectural elements, and/or traffic infrastructure elements), and type information relating to shapes and/or symbols for such other features.

Facilities maps may include additional information that may be useful to a quality assessment process. For example, various information that may be included in a legend of the facilities map, or otherwise associated with the facilities map (e.g., included in the metadata or otherwise represented on the map), and available for use in a quality assessment process, may include, but is not limited to, a date of the facilities map (e.g., when the map was first generated/created, and/or additional dates corresponding to updates/revisions), a number of revisions to the facilities map (e.g., revision number, which may in some instances be associated with a date), one or more identifiers for a source, creator, owner and/or custodian of the facilities map (e.g., the owner of the facility type represented in the map), various text information (e.g., annotations for one or more aspects or elements of the map), and any other legend information that may be included or represented in the map.

FIG. 7 shows an example of a visual representation of a portion of an electronic facilities map 500. In this example, facilities map 500 is a telecommunications facilities map that is supplied by a telecommunications company. Facilities map 500 shows telecommunications facilities in relation to certain landmarks, such as streets and roads, using lines and shapes. As discussed above, the electronic facilities map may include metadata indicating what various lines, symbols and/or shapes represent, and indicating the geo-location of these lines, symbols and/or shapes. With respect to exemplary environmental landmarks, facilities map 500 may include both visual information and metadata relating to utility poles 502, manhole 504, and any of a variety of other landmarks that may fall within the geographic area covered by the facilities map 500.

IV. Exemplary Automated Assessment Methods

FIG. 8 shows a flow diagram of an exemplary process 1300 for performing a quality assessment of an underground facility locate and/or marking operation, as implemented by automated quality assessment application 1200. While the examples provided in FIG. 8 is a more specific example of the generic process 1900 discussed above in connection with FIG. 3, and describes an automated quality assessment based on a completed or closed ticket for which it is presumed that a locate and/or marking operation was actually performed by a technician, it should be appreciated that the concepts generally outlined in the process 1300 may be applied to various types of available information relating to a requested locate operation and marking operation, whether performed separately or in tandem, and irrespective of actual performance of the locate operation and/or the marking operation, so as to assess the quality of the requested operation.

Process 1300 begins at act 1310, where a completed (i.e., closed) ticket is received and associated information to be used in assessing the quality of the locate and marking operation performed in connection with the ticket is collected by automated quality assessment application 1200. The associated ticket information may include, for example, the originating ticket information (e.g., textual ticket information 1222 of a certain ticket 1220), and one or more of the VVL images (e.g., a VVL image 1232 of a certain ticket 1220), the originating ticket assessment (e.g., a ticket assessment outcome 1242 of a certain ticket 1220), the locating equipment data (e.g., marking device data 1252 and/or locate receiver data 1254 of a certain ticket 1220), the EM.
images (e.g., a EM image 1262 of a certain ticket 1220), and any other information (e.g., from other electronic information and/or records 1295).

The process then continues to act 1312, where the received information is used to automatically assess the quality of the locate and marking operation. In the example of FIG. 8, a locate operation is categorized as either (a) APPROVED—the operation is approved, no further action needed; (b) SATISFACTORY—the operation is approved, but the locate technician needs coaching or training; (c) UNSATISFACTORY—the operation is not approved, the ticket needs QC action; or (d) PROMPT—an aspect of the operation assessment may be suitable for transmitting a real-time prompt to the locate technician with respect to, for example, performing a substantially immediate verification and/or corrective action. However, the invention is not limited in this respect, as any suitable indication of quality may be provided as a result of an automatic quality assessment, such as, a numerical score (e.g., a score from 0-100%), a letter grade, another type of graduated indicator based on some scale or range, or any other indication of quality. Additional details and examples of how quality may be automatically assessed at act 1312 and an indication (e.g., a categorization) of quality may be automatically generated at act 1314 are discussed below. It should be appreciated that the invention is not limited to these particular examples, and that such examples are provided primarily for the purposes of illustration.

V. Assessments Relating to Environmental Landmarks

In some embodiments, the quality assessment of a locate and/or marking operation performed in act 1312 of FIG. 8 may be based entirely or in part on a comparison of information about the performance of the locate and/or marking operation (e.g., “field information,” i.e., one or more of locate information, marking information, landmark information and EM information, obtained from one or more of a locate device, a marking device, a combination locate and marking device, and an EM application executing on any of a variety of computing devices) and reference information relating to one or more environmental landmarks. In exemplary embodiments in which the reference information comprises data relating to one or more environmental landmarks (“landmark information,” e.g., geographic information and/or landmark category/type information relating to one or more environmental landmarks), a variety of assessments are possible.

For example, in a first embodiment relating to environmental landmarks, field information including geographic information, facility type information, and/or other information relating to an underground facility identified and/or marked during a locate and/or marking operation may be compared to reference information comprising landmark information to determine whether or not the location and/or type of one or more facilities identified and/or marked during the locate and/or marking operation are expected in view of the location and/or type of one or more environmental landmarks. Such a comparison may include identifying at least one correspondence or discrepancy between the compared data based on one or more criteria. The landmark information may be derived, for example, from one or more facilities maps, one or more historical tickets, or may be collected together with (e.g., essentially concurrently with) various information relating to the locate and/or marking operation (the locate and/or marking operation to be assessed may include acquisition of landmark information relating to one or more environmental landmarks, and this landmark information may be used for the assessment).

In a second exemplary embodiment relating to environmental landmarks, “new” landmark information collected as part of a current/recent locate and/or marking operation (e.g., via a suitably configured marking device, locate device, or combined locate and marking device, and/or indicated on an electronic manifest for the locate and/or marking operation) may be compared to “reference” landmark information. The reference landmark information may be derived, for example, from one or more facilities maps or one or more historical tickets (which themselves may include previous electronic manifests), and such a comparison may serve as a basis for assessment. In one aspect of this embodiment, both “new” landmark information and other information relating to the locate and/or marking operation (e.g., geographic information, facility type information, etc.) may be compared to the reference landmark information and other facility-related information derived from one or more facilities maps, one or more historical tickets, or other information sources, such that an assessment is based both on a comparison of environmental landmarks and facilities. In some exemplary embodiments discussed in greater detail below, geographic information in the field data is compared to geographic information in the reference data. For example, field geo-location data (e.g., one or more sets of latitude and longitude coordinates) relating to the detection and/or marking of a given underground facility or other activity during a locate and/or marking operation, and/or field geo-location data relating to one or more environmental landmarks, may be compared to reference geo-location data relating to one or more environmental landmarks.

More specifically, in some implementations, latitude and longitude coordinates corresponding to a detected and/or marked facility, and/or latitude and longitude coordinates corresponding to one or more environmental landmarks (field geo-location data), are compared to latitude and longitude coordinates (transformed if necessary to a common reference frame) relating to one or more environmental landmarks (reference geo-location data). In this manner, a correspondence or discrepancy (or degree of correspondence) may be ascertained between the field geo-location data and the reference geo-location data.

As discussed in greater detail below, a first set of field latitude and longitude coordinates, constituting lines or curves representing underground facilities detected and/or marked during the locate and/or marking operation, and/or one or more latitude and longitude coordinates constituting points or polygons representing environmental landmarks, may be compared to a corresponding set of reference latitude and longitude coordinates to determine a degree of matching between the two sets, in a manner akin to pattern matching. Additionally or alternatively, such sets of points may be compared to determine some relationship between the sets of points that bears upon an assessment (e.g., do the end points of a given facility line of a particular facility type essentially correspond to a geographic location of one or more environmental landmarks relating to that facility type?). This may be useful in determining not only how closely the locate marks formed by the technician correspond to the presumed physical location(s) of the underground facilities, but also if the detection and/or marking of a particular facility line “makes sense” in the context of its environment, based on various landmarks in the environment.

Although comparisons of field geo-location data and reference geo-location data to facilitate an automated quality assessment process are described in some exemplary embodiments discussed in greater detail below, it should be
appreciated that more generally, in other embodiments, a variety of other information contained in field information/data and reference information/data may be used as a basis for an automated quality assessment. For example, field information pertaining to the number and/or types of facilities detected and/or marked during a locate and/or marking operation, and/or the number and/or types of environmental landmarks present (or that no landmarks are present), may be compared to similar reference information derived from one or more facilities maps, historical tickets, etc., without regard to geographic information (e.g., by noting from various sources of reference information what types of landmarks are present or not present corresponding to a given work site/dig area, and/or how many landmarks of a particular type are present or not present). In this respect, it should be appreciated that the absence of landmarks in a given geographic area, or absence of landmarks of a particular type in a given geographic area, constitutes useful landmark information. For example, field data relating to the a marked facility line that terminates at a point at which there is no landmark present (e.g., of an appropriate category and/or type for the facility line in question) may indicate an erroneous or incomplete marking operation; in this sense, the reference information relating to one or more environmental landmarks includes information about the absence of any landmarks (e.g., in a location where one might otherwise be expected).

In another example, field information pertaining to an arrangement or pattern (i.e., relative positions) of multiple lines for a same type of facility, multiple different facility types detected and/or marked during a locate and marking information, and/or multiple environmental landmarks may be compared to similar reference information ("relative position information") derived from any one or more sources of reference information pertaining to environmental landmarks, irrespective of the presumed physical geographic location(s) of the respective facilities/lines/landmarks (i.e., the general pattern of lines and/or landmarks detected and/or marked in the field may be compared to the general pattern of landmarks as represented in reference information). The foregoing and other examples of assessments based on different types of information relating to environmental landmarks is discussed in further detail below in connection with various embodiments.

FIGS. 9A and 9B provide illustrative depictions based on various information that may be available, according to one embodiment, relating to locate and/or marking operations, which information may facilitate an assessment of the operation based at least in part on landmark information. As discussed in greater detail below, various information derived from electronic records generated by locate equipment, electronic manifests, tickets, facilities maps, and the like may be visually rendered in a display field (e.g., of a display coupled to the system 1800 shown in FIG. 2) to provide a visual aid in connection with an assessment process. In some exemplary implementations, electronic visual renderings may be provided by an EM (electronic manifest) application, as discussed above. For purposes of illustrating various concepts relating to analysis and assessment of locate and/or marking operations based on landmark information, FIG. 9A illustrates a first electronic visual rendering 1600A of a first locate and/or marking operation and FIG. 9B illustrates a second electronic visual rendering 1600B of a second locate and/or marking operation.

In FIGS. 9A and 9B, marking information (and/or locate information), as well as landmark information, are used to provide the exemplary electronic visual renderings, showing the relative positions of various elements. For example, the electronic rendering 1600A shown in FIG. 9A includes a first lines pattern 1610 representing a power line, and a second lines pattern 1612 representing a telephone line, each of which includes electronic locate marks representing corresponding physical locate marks placed on ground, pavement or other surface during a marking operation (it should be appreciated that additionally, or alternatively, locate information representing where a given underground facility was detected may be used for such electronic visual renderings). Similarly, FIG. 9A shows various identifiers (e.g., symbols, icons, lines or patterns, etc.) for multiple environmental landmarks; in particular, a building 1614, a pedestal 1618, a utility pole 1616, and a curb 1620 are shown in the electronic rendering 1600A. For purposes of the present discussion, it is presumed that geographic information (e.g., geo-location data points, such as GPS coordinates) from one or more information sources (e.g., electronic records) is available for the depicted lines pattern and the environmental landmarks, and such geographic information forms the basis for the electronic visual rendering, as to appropriately illustrate the relative positions of various elements shown.

The relative positions of electronic locate marks representing marked (and/or detected) underground facilities and one or more environmental landmarks in or proximate to the work site/dig area in which the facilities were marked (and/or detected) often provide valuable information toward assessing the accuracy and/or completeness of a locate and/or marking operation. For example, as shown in FIG. 9A, given the presence of the utility pole 1616 and the building 1614, it would be expected to encounter the lines pattern 1610, representing an electrical power line, traversing some path between the utility pole 1616 and the building 1614. Furthermore, the presence and footprint of the curb 1620 may be instructive, as in some situations it would be expected to encounter some types of underground facilities (such as the power line represented by the lines pattern 1610) following the general footprint and path of the curb (e.g., running essentially parallel to the curb, perhaps at a particular offset; to this end, in some instances an environmental landmark such as the curb may provide a reference point for a "tie down" to the underground facility). Similarly, given the presence of the pedestal 1618, it would be expected to encounter the lines pattern 1612, representing a telephone line, traversing some path between the pedestal and the building.

In view of the foregoing examples, it should be appreciated that a variety of environmental landmarks may be utilized according to the inventive concepts described herein as instructive reference points to determine the feasibility and/or expectation of encountering an underground facility, and thereby facilitate an assessment of the locate and/or marking operation. For example, for the marking operation depicted in FIG. 9A, geographic information relating to the electronic locate marks representing marked utilities may be compared to geographic information relating to the environmental landmarks to assess accuracy and/or completeness. A variety of criteria and/or metrics for one or more criteria may be used in such an assessment, as discussed in greater detail below. In particular, the presence of the utility pole 1616 in or near the work site suggests that a power line should be detected and marked; the presence of the building 1614 suggests that the power line should follow some path between the utility pole and the building. Accordingly, geo-location data points representing the end points of the marked power line may be compared to geo-location data points representing one or both of the utility pole and a
corner of the building (for example) to determine a degree of correspondence or discrepancy between these data points (e.g., Are the end points of the electronic locate marks for the power line within some threshold distance of the utility pole and/or the building? Does the power line extend completely between the utility pole and the building, or does it appear to terminate in the middle of nowhere?). A similar comparison may be done for geo-location data points representing the electronic locate marks for the telephone line (lines pattern 1612) and geo-location data points for the pedestal 1618 (e.g., Are the end points of the electronic locate marks for the telephone line within some threshold distance of the pedestal and/or the building?).

While the scenario illustrated in FIG. 9A provides an example of a “satisfactory” marking operation according to exemplary criteria in that facility lines are marked as expected with reference to noted environmental landmarks, the scenario illustrated in FIG. 9B illustrates an incomplete and possibly suspect or “unsatisfactory” marking operation according to some exemplary criteria. For example, an assessment method based on environmental landmarks may first note all environmental landmarks for which information is available (e.g., geo-location data for landmarks, type data for landmarks, etc.) and, for each landmark, examine other available information for any facilities detected and/or marked in or near the environmental landmark (e.g., within some radius or threshold distance of one or more geo-location data points for the landmark). If no such detected and/or marked facility is found, and indication of a suspect (e.g., may need follow-up and/or coaching) or unsatisfactory quality assessment may be provided.

With the foregoing in mind, it may be observed from FIG. 9B that, in this second marking operation represented by the electronic rendering 1600B, there is no lines pattern 1612 representing the telephone line, notwithstanding the presence of the pedestal 1618. Thus, in assessing the available information in this scenario, the presence of the pedestal 1618 without any telephone lines marked in the vicinity of the pedestal suggests that the locate and/or marking operation is perhaps incomplete, and may be indicated accordingly as suspect (e.g., needs follow-up and/or coaching) or unsatisfactory. In another example based on the foregoing, an assessment process may similarly provide an indication of a suspect or unsatisfactory locate and/or marking operation if a type of facility is found terminating at or intersecting an environmental landmark of a type that is inconsistent with the facility type (e.g., a power line terminating at or near a fire hydrant). In yet another example, an assessment process may similarly provide an indication of a suspect or unsatisfactory locate and/or marking operation if an offset between a detected and/or marked line and an environmental landmark serving as a tie-down (e.g., the offset between the curb 1620 and the lines pattern 1610) is not within some prescribed threshold distance.

In the foregoing example, information relating to one or more facility lines detected and/or marked during a locate and/or marking operation was compared to landmark information. In another embodiment, “new” landmark information collected as part of a current/recent locate and/or marking operation (e.g., via a suitably configured marking device, locate device, or combined locate and marking device, and/or indicated on an electronic manifest for the locate and/or marking operation) may be compared to “reference” landmark information (e.g., derived from one or more facilities maps or one or more historical tickets), and such a comparison may serve as a basis for assessment. In one aspect, such an assessment may focus primarily on the consistency or inconsistency of landmark information at or near a same work site. To this end, any landmark information available in an electronic record of a locate and/or marking operation may be compared to any landmark information from available reference information; in one exemplary implementation, geographic information (e.g., geo-location data points) for any landmark represented in landmark information from the field may be compared to reference geographic information for landmarks. As with the exemplary assessments discussed above in connection with FIGS. 9A and 9B, any geographic information relating to either facility lines or environmental landmarks may be compared, in some instances on a per geo-location data point basis, to determine distances between compared points and make various assessments based thereon (e.g., is the distance between two points, or two sets of points, within some predetermined threshold).

More specifically, in one embodiment, a set of “field” geo-location data points (e.g., representing facility line or environmental landmark geographic information relating to a locate and/or marking operation) may be compared to the set of “reference” geo-location data points relating to environmental landmarks serving as a basis for assessment, to determine geographic distance between them. Such a comparison may be executed in block 1312 of one exemplary implementation of the process 1300 shown in FIG. 8.

In particular, FIG. 10 shows an illustrative process 700 for determining distance between points in two sets, X and Y, of geo-location data points (the process 700 may be executed in block 1312 of the process 1300). Each of these sets may include a plurality of geo-location data points (e.g., latitude and longitude values or x,y coordinate pairs), and the geo-location data points in set X typically are in the same reference frame (e.g., coordinate system) as the geo-location data points in set Y. In embodiments in which the process 700 is used to compare a set of field geo-location data points to a set of reference geo-location data points relating to one or more environmental landmarks, set X may include the field points and set Y may include the reference points. Process 700 defines the distance between the two sets X and Y as a vector of distances d_0, . . . , d_n, where each distance d_i indicates the distance between a point x_i in set X and the point y_i in set Y that is closest to x_i.

Referring to FIG. 10, the illustrative process 700 begins at act 10 by initializing a variable n to zero. The process continues to act 20, where a point x_n in the set X is selected, where x_n is the n-th point in the set X. The process next continues to act 30, where the point in set Y that is closest to the point x_n is identified and is set as the variable y_m. That is, among all the points in the set Y, the selected point y_m is the one closest to point x_n. The process then continues to act 40, where the distance between x_n and y_m is recorded and stored in the variable d_n. The process next continues to act 50, where it is determined whether there are any more points in the set X to process. When it is determined that the set X contains one or more points yet to be processed, the process 700 continues to act 60, where the value of n is incremented by one. The process then returns act 20, where the next point in the set X is selected. If, at act 50, it is determined that there are no more points in set X to process, the process 700 ends.

It should be appreciated that each of the sets X and Y may include any number of geo-location data points, as the present disclosure is not limited in this respect. For example, in some embodiments, one or both of the sets may have only one geo-location data point specifying a single point on
Earth. In other embodiments, one or both sets may have multiple geo-location data points specifying multiple points on Earth.

Additionally, the process 700 may be applied to determine a measure of distance between any two sets of points in any space in which a measure of distance can be defined between two points. Thus, the application of the process 700 is not limited to geo-location data points expressed in an absolute frame of reference that ties the geo-location data to specific points on Earth. For example, in some embodiments, the geo-location data points in set X and set Y may not be expressed in latitude and longitude, but rather may be expressed as locations (e.g., distance and direction) relative to some other reference point (e.g., an arbitrary reference point, a reference point defined by one or more facilities maps, a reference point defined by some environmental landmark, or some other reference point).

The process 700 is also not limited to any particular technique for determining the distance between two points, as any of numerous techniques may be used. For example, in an embodiment where the geo-location data points are expressed in latitude and longitude coordinates, a distance between two points may be calculated according to the great-circle distance in spherical geometry, using Vincenty’s inverse method for computing geographical distance between two points, or using some other method. In some embodiments in which the coordinates for the two points are each two-dimensional Cartesian coordinates in a common grid system, the straight line distance between these two points may be determined using the following formula:

\[ d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \]

In embodiments in which the process illustrated in FIG. 10 is used to perform the function indicated in block 1312 of the process 1300 shown in FIG. 8, in some exemplary implementations the quality assessment may be based on the distance between any two closest points compared (e.g., a geo-location data point from the field data corresponding to a fire hydrant, and a closest geo-location data point from the reference data corresponding to a fire hydrant as represented in a facilities map covering the area of the work site). In particular, the assessment may establish a threshold distance for each pair within which the distance between the respective compared geo-location data points must fall. A unique threshold distance may be established for different pairs of points, or similar/same threshold distances may be established for groups of points or all of the data compared. Furthermore, in various implementations, the type of points compared from the field and reference data sets may be depend on the nature of the assessment; for example, in one implementation, termination points of facility lines of a particular type from the field data are compared to reference geo-location data points of environmental landmarks of a particular type to assess if the facility line(s) appropriately terminate at an expected environmental landmark.

In yet other implementations, a percentage of field geo-location data points that are within a threshold distance of corresponding reference geo-location data points may be used as a basis for assessment. That is, as discussed above, the process of FIG. 10 generates a vector of distances \( d_1, \ldots, d_n \), where each distance \( d \) indicates the distance between one field geo-location data point and one reference geo-location data point. Thus, in some embodiments, the quality assessment may be based on the percentage of these distances that are within some predetermined range or threshold.

Table 7 shows one possible technique for generating a quality assessment of a locate and/or marking operation in this way using a scoring table. Techniques for generating a scoring table and computing a score using a scoring table are described in greater detail in U.S. Non-provisional patent application Ser. No. 12/493,109, filed Jun. 26, 2009, entitled "Methods and Apparatus for Quality Assessment of a Field Service Operation," incorporated by reference herein. As shown in Table 7, the criterion on which the quality of locate and/or marking operation is being assessed is listed in the leftmost column. For this criterion, the table includes one or more expected or reference values or ranges for the criterion, also referred to as "metrics," against which information about the locate and/or marking operation is measured/compared. The metrics are divided into several "scoring categories," namely, value(s)/condition(s) that, if met, result in a particular score.

For purposes of the analysis illustrated in Table 7, field information/data is referred to as ACTUAL DATA, and reference information/data is referred to as EXPECT DATA. A quality assessment for the indicated criterion is based on a comparison of the ACTUAL DATA to the EXPECT DATA (e.g., so as to determine in what scoring category the ACTUAL DATA falls as a result of the comparison). For purposes of the discussion that follows, although examples based on numeric scores are provided, the term "score" as used herein is intended to more generally denote any of a variety of graduated indicators for a quality assessment (which in turn may be based on a variety of ranges, scales and resolutions/ granularity for the indicators).

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Preferred</th>
<th>Marginal</th>
<th>Unacceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXP: Distance between field landmark and reference landmark</td>
<td>Within 1 foot</td>
<td>Greater than 1 foot</td>
<td>Greater than 2 feet</td>
</tr>
<tr>
<td>ACT: Distance between field landmark and reference landmark</td>
<td>8 inches</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In the example of Table 7, the criterion on which the quality of the locate operation is being assessed is the distance between a landmark represented in the field data, and the same type of landmark represented in the reference data. Additionally, in this example, there are three scoring categories: Preferred; Marginal; and Unacceptable. For each scoring category, there is a metric used to evaluate the contents of the distance vector \( [d_1, \ldots, d_n] \) resulting from the comparison of the field data to the reference data to determine in which scoring category the results of the comparison fall. In the example of Table 7, an evaluation of the distance vector shows that, for the landmark in question, the distance between the field data and the reference data was within one foot, and hence falls into the preferred category.

With reference again to act 1905 of FIG. 3 (or, similarly, act 1314 of FIG. 8), in some embodiments a score, grade, or categorization may be assigned as an output to categorize the quality assessment process based on into which scoring category the assessment falls. For example, in some embodiments, each scoring category may be associated with a number of points (e.g., 2 points for Preferred, 1 point for Marginal, and 0 points for Unacceptable), and the quality assessment may be awarded the number of points associated with the scoring category into which it falls. Thus, for
example, in the example of Table 7, 2 points may be awarded, because the operation falls in the “Preferred” scoring category.

In some embodiments, the number of points awarded may be converted to a percent score that is based on the number of points awarded and a maximum possible number of points. Thus, for example, in the example of Table 7, the locate and/or marking operation received two points out of a maximum possible two points. As such, the locate and/or marking operation may be assigned a score of 2/2 or 100%. If the assessment results were to fall in the “Marginal” category and receive only one point, then it may be assigned a score of 1/2 or 50%. Similarly, if the assessment results were to fall in the unacceptable category and receive zero points, then it may be assigned a score of 0/2 or 0%.

In some embodiments, a range of percent scores may be converted to letter scores to provide an indication of quality. For example, a percent score of 100-90% may be converted to a letter score of A, 89-80% may be converted to a letter score of B, 79-70% may be converted to a letter score of C, 69-60% may be converted to a letter score of D, and <60% may be converted to a letter score of F. In yet another example, a range of percent scores may be converted to a simple PASS/FAIL score. For example, a percent score of 100-60% may be converted to a score of PASS and a percent score of <60% may be converted to a score of FAIL.

In some embodiments, the quality assessment illustrated in Table 7 may be used in the process of FIG. 8 to categorize the locate and/or marking operation as either “Approved” “Coach” or “QC Referral.” For example, Table 7 may be used at act 1312 to assess the quality of the locate and/or marking operation. Based on this assessment, the quality of the operation may be categorized at act 1314. For example, if the operation falls in the “Preferred” scoring category in Table 7 it may be categorized as “Approved” at act 1314; if the operation falls in the “Marginal” scoring category, it may be categorized as “Coach,” and if the operation falls in the “Unacceptable” scoring category it may be categorized as “QC Referral.”

In the example of Table 7, three scoring categories are used, such that the locate and/or marking operation is classified as either Preferred, Marginal, and Unacceptable. However, the number of scoring categories is merely illustrative, as any number of scoring categories could be used, and various mutually exclusive metrics may be assigned to these scoring categories. For example, in some embodiments, five scoring may be used (e.g., Excellent, Good, Average, Poor, Unacceptable), while in other embodiments more than five scoring categories may be used.

In addition, it should be appreciated that the distance threshold values used in the metrics in Table 7 are merely illustrative and that a variety of different percentage values and distance threshold values may be used. In some embodiments, the distance threshold values may be based on legal requirements pertaining to locate and/or marking operations. For example, some governments (e.g., state governments) may dictate certain “tolerance zones” around underground facility lines or landmarks relating to same (e.g., 12 inches, 18 inches, 24 inches, 30 inches, 36 inches, etc.). Thus, in some embodiments, one or more of the metrics used in a scoring table may be based on a tolerance zone dictated by government regulations.

VI. Visual Representations

In some embodiments, as discussed above, any of the field information and reference information available to the assessment process (from any of a variety of sources) may be visually rendered in a display field (e.g., of a display coupled to the system 1800 shown in FIG. 2) to provide a visual aid in connection with an assessment process. In some exemplary implementations, electronic visual renderings may be provided by an EM (electronic manifest) application, as discussed above. According to one aspect of this embodiment, it is particularly instructive as a visual aid to “overlay” some or all of the contents of the field information with that of the reference information in the display field, so as to provide a visual comparison of the information (e.g., as a supplement to the automated/computer comparison of various elements of the available field and reference information). To aid in such a comparison, different facility types may be indicated in the display field, for example, by employing different colors or line types, and different environmental landmarks may be indicated in the display field, for example, by employing different colors, shapes, patterns, icons, etc.

FIG. 11A illustrates an electronic visual rendering in the form of an overlay 990A for a first locate and/or marking operation, in which the field information includes marking information and landmark information (to constitute a “recreated locate operation” 800), and the reference information includes information relating to both facility lines and landmarks as derived from one or more facilities maps so as to provide an “aggregated map” 905. Each of the field information and reference information includes respective elements representing facilities lines and environmental lands (e.g., lines pattern 816 corresponding to telecommunications line 916, utility pole 852 corresponding to utility pole 952, lines pattern 810 corresponding to power line 910, pedestal 854 corresponding to pedestal 954, fire hydrant 856 corresponding to fire hydrant 956, etc.). From the overlay 990A of FIG. 11A, a viewer may obtain an “at-a-glance” qualitative view of the field information as compared to the reference information.

Electronic visual renderings such as the overlay 990A shown in FIG. 11A may be useful in highlighting possible discrepancies between field information and reference information. For example, FIG. 11B illustrates another electronic visual rendering of an overlay 990B for a second locate and/or marking operation, in which the viewer may discern a discrepancy between one of the lines patterns represented by electronic locate marks based on the field information, and a corresponding facility line in the reference information. In particular, the lines pattern 810 in the recreated locate operation 800 shown in the overlay 990B of FIG. 11B is noticeably offset from what would appear to be the closest corresponding facility line, i.e., the power line 910, as represented by geographic information in the reference information. Thus, the overlay 990B provides a useful visual tool for further assessing the locate and/or marking operation based on available field information and reference information.

To further facilitate visual observations of available information from electronic renderings, in one embodiment, each of the field information/data and the reference information data, if present in a computer-aided visual rendering, as well as any constituent information forming part of the field data and the reference data, may be displayed as separate “layers” of the visual rendering, such that a viewer of the visual rendering may turn on and turn off displayed data based on a categorization of the displayed data. For example, all field data may be categorized generally under one layer designation (e.g., “Field”), and independently enabled or disabled for display (e.g., hidden) accordingly. Similarly, all reference data may be categorized generally under another layer designation (e.g., “Reference”) and independently enabled
The inventors have further appreciated that conventional ticket processing systems used by locate service providers may have limited assessment capabilities. That is, conventional ticket processing systems may offer limited capabilities in deriving information that is not explicitly included in the incoming tickets. For example, little or no assessment is done to estimate various aspects (or attributes) of a requested locate operation, such as location, scope, duration, complexity, risk, value, skill requirements and the like. The lack of information regarding these and other aspects of locate operation tickets may lead to various inefficiencies, e.g., in the scheduling of the locate operations and/or the allocation of resources to the locate operations. There may also be an increased risk of damaging underground facilities. As a result, profitability of the locate service providers may be adversely affected.

Thus, the inventors have recognized a need for improved information management, dissemination, and utilization in the locate industry and other field service industries in which mobile technicians are dispatched in response to incoming service requests.

In view of the foregoing, one embodiment of the present invention is directed to an apparatus for assessing one or more attributes of a locate operation requested in a locate operation ticket. The apparatus comprises at least one processor programmed to extract ticket information from the locate operation ticket at least in part by parsing the locate operation ticket; apply one or more business rules to at least some of the ticket information to obtain a ticket assessment outcome for each of the one or more attributes; and dispatch at least one locate technician to perform the locate operation, based at least in part on the ticket assessment outcome for each of the one or more attributes.

Another embodiment is directed to an apparatus for assessing a complexity of one or more locate operations requested in a locate operation ticket. The apparatus comprises at least one processor programmed to extract one or more information elements from the locate operation ticket, and associate one or more complexity types to the locate operation ticket based at least in part on the one or more information elements.

Another embodiment is directed to an apparatus for assessing a level of risk associated with one or more locate operations requested in a locate operation ticket. The apparatus comprises at least one processor programmed to extract one or more information elements from the locate operation ticket, and determine a risk value associated with the locate operation ticket based at least in part on the one or more information elements.

1. Overview

Various embodiments described herein relate to systems, methods and apparatus for improved information management, dissemination and utilization in field service operations in which mobile technicians are dispatched in response to service requests. In particular, some exemplary embodiments relate to systems, methods and apparatus for automatically and intelligently assessing locate operation tickets to provide information that can be used to improve activity scheduling, resource allocation, quality control, and/or regulatory compliance. While the particular example of locate operation tickets is provided herein primarily for purposes of illustration, it should be appreciated that the inventive concepts described herein may be more generally applicable to other types of field service operations.

As discussed above, the inventors have appreciated that there is a lack of an established data standard for use when sharing information among various entities in the locate
industry, such as excavators, one-call centers, facility owners and locate service providers. As a result, the availability and consistency of data may not be always guaranteed. Accordingly, in some exemplary embodiments, a ticket management system is provided that associates a level of confidence with at least some input data to indicate how reliable the data is. For example, a level of confidence may be assigned to a data unit as it enters the ticket manage system, so that the propagation of unreliable information may be limited. In some embodiments, confidence levels may be used to resolve conflicts, so that information from a more trustworthy source may be chosen over information from a less trust-worthy source. Additionally, multiple related pieces of information may be compared, and a confidence level may be increased when the related pieces of information are consistent with each other.

In some further embodiments, a ticket management system is provided that includes a ticket assessment engine for analyzing incoming locate request tickets. The ticket assessment engine may be programmed to derive useful information that is not directly available from the tickets themselves. A number of different types of assessments may be performed, including, but not limited to, the following.

Location: Location of planned excavation (or, equivalently, location of work site). In some instances, insufficient location information may be provided in a locate request ticket. For example, a location description may be vague or ambiguous (e.g., a street name without any house numbers). As another example, multiple conflicting pieces of location information may be given (e.g., a street address and a pair of lat/long coordinates that do not match). In these situations, additional analysis may be needed to ascertain the location of the work site.

Scope: Amount and nature of work. For example, the size of a dig area, as measured in length or in area, may be indicative of the scope of a requested locate operation. The depth of excavation and the number of different facilities involved may also be relevant.

Complexity: Complexity involved in performing a locate operation. For example, a locate operation may be classified as high complexity when a high profile facility asset (e.g., fiber-optic communication cables) is involved or when the work site is in a restricted access area (e.g., a military base or gated community).

Duration: Amount of time needed to perform a locate operation, which may be determined by scope (e.g., the number and types of different facilities involved) and/or complexity (e.g., delays due to access restrictions).

Risk: Potential liability for damages when a locate service provider is at fault (e.g., failing to complete a locate operation by a required deadline or inadequately performing a location operation). For example, a locate operation involving one or more main utility lines (e.g., water mains serving an entire neighborhood) may be considered high risk, while a locate operation involving only service lines (e.g., utility lines leading to a customer’s premise) may be considered low risk.

Value: Business value of performing a locate operation. In some embodiments, value may simply be the revenue collected for the locate operation. In other embodiments, various operating costs may be subtracted from the revenue. In some further embodiments, a more sophisticated measure such as value at risk may be used.

Skill requirements: Personnel skill level or certification required to perform a locate operation. For example, in some jurisdictions, only a technician with gas certification may be dispatched to perform a locate operation involving gas pipes. In some embodiments, personnel skill level may encompass both long term measurements, such as years of experience, and short term measurement, such as recent performance evaluations.

The inventors have appreciated that the assessment outcomes provided by a ticket assessment engine may be used to improve various aspects of the business operations of a locate service provider, such as activity scheduling, resource allocation, quality control, and/or regulatory compliance. In some embodiments, the ticket assessment engine may be programmed to provide an estimated measurement, ranking, score, classification and/or some other suitable value for each of the assessment targets listed above, or any other desirable assessment targets. These outcomes may then be input into one or more other components of the ticket management system, for example, an activity scheduling application, a ticket review application for quality control and training, and/or a customer billing application.

The ticket assessment engine may access various information sources in order to produce the desired assessment outcomes. For example, the ticket assessment engine may make use of facility plats available from the facility owners to determine whether certain geographical areas should be classified as high risk or high complexity areas. As another example, the ticket assessment engine may access a database containing past damage reports to determine whether a given excavator has a history of frequent and/or costly damages. As yet another example, the ticket assessment engine may access a database containing information regarding previously completed tickets to search for notes and/or remarks regarding a given geographical location.

Following below are more detailed descriptions of various concepts related to, and embodiments of, inventive systems, methods and apparatus for improved information management, dissemination and utilization in field service applications and, in particular, for assessing locate operation tickets. It should be appreciated that various concepts introduced above and discussed in greater detail below may be implemented in any of numerous ways, as the disclosed concepts are not limited to any particular manner of implementation. For instance, the present disclosure is not limited to the particular arrangements of components shown in the various figures, as other arrangements may also be suitable. Such examples of specific implementations and applications are provided primarily for illustrative purposes.

Generic terms such as “engine,” “application” or “module” may be used herein when referring to one or more of software components of a ticket management system. Such terms should not be interpreted as being limiting in any way. Also, each of the software components described herein may be implemented in any suitable way, for example, as processor-executable instructions stored in at least one physical storage device (e.g., a non-volatile memory device and/or a volatile memory device) of a general purpose computer or some other suitable hardware system. The general purpose computer or hardware system may comprise at least one hardware processor for executing the instructions stored in the physical storage device, and may further comprise at least one input/output (I/O) interface for receiving inputs from input sources or devices and for sending outputs to output recipients or devices. In some embodiments, the hardware processor on which a software component executes may be in a mobile or portable device, such as a mobile telephone, personal digital assistant, a marking device (e.g., for spray painting lines or other marks on the ground), or any other type of mobile or portable device.
2. System Architecture and Components

FIG. 12 shows an example of a ticket management system 2200 comprising a number of software components for performing various functions, such as parsing incoming locate operation tickets, assessing parsed tickets according to appropriate business rules, and scheduling and dispatching locate technicians to perform locate operations. Generally, the ticket management system 2210 may be a management software application run by a locate service provider, such as the locate service provider 2130 (similar to the locate service provider 130 shown in FIG. 1), although this is not required.

In the embodiment shown in FIG. 12, the ticket management system 2200 receives locate operation tickets 2205 from one or more suitable sources, such as the one-call center 2120 (similar to the one-call center 120 shown in FIG. 1). Each ticket typically includes one or more text strings describing various parameters of the requested locate operation, such as time, location and types of facilities. In some instances, one or more images depicting the work site and/or dig area may also be attached to the ticket.

Depending on the originating one-call centers, different types of information may be stored in the text portions of the tickets 2205 in different formats. Therefore, a ticket parser 2210 may be provided, which may be programmed to recognize an origin of a ticket 2205 and perform the parsing accordingly to output a parsed ticket 2215. The parsed ticket 2215 may be created according to a standardized ticket format, which may be any suitable set of rules or conventions for representing and organizing data, designed to facilitate efficient handling of data by various software components. For example, the standardized format may be an Extensible Markup Language (XML) format. Further details regarding ticket parsing are described below in connection with FIG. 15.

In the embodiment shown in FIG. 12, the parsed ticket 2215 is stored in a ticket database 2220, along with any images of the work site and/or dig area attached to the ticket 2205. The ticket database 2220 may be any substantially persistent storage of data, for example, a relational database that is created and maintained using a suitable database software. The relational database may store relationships between excavation companies, one-call centers, facility owners, locate service providers, facility maps, locate request tickets, and the like.

The parsed ticket 2215, along with any associated images, may be retrieved from the ticket database 2220 in a suitable manner and supplied to a ticket assessment engine 2230 for processing and analysis. In some instances, the ticket assessment engine 2230 may create one or more work orders (e.g., work orders 2235A-C) upon receiving the parsed ticket 2215 and may assess each of the work orders individually. For example, the ticket assessment engine 2230 may determine that one or more prerequisite activities must be completed before the requested locate operation can be undertaken (e.g., a safety personnel must be dispatched to ensure that a manhole is clear of any hazardous gases before a locate technician may enter the manhole to perform a requested locate operation). In that situation, the ticket assessment engine 2230 may create a work order for each of the prerequisite activity and the requested locate activity.

As another example, the parsed ticket 2215 may be a so-called “project ticket,” which requires a large number of man hours to complete. For instance, the work site may be several miles along a highway, or may include an entire housing development complex. The ticket assessment engine 2230 may break up such a project in a suitable manner into multiple work orders and assess each work order individually. When appropriate, subsequent processing such as scheduling and dispatch may also be performed on a per work order basis.

In the embodiment shown in FIG. 12, the ticket assessment engine 2230 applies an appropriate set of business rules 2240 to evaluate the work orders 2235A-C. For example, there may be different business rules for assessing each of the following aspects: location, scope, complexity, duration, risk, value and skill requirements. Exemplary business rules for some of these aspects are described in greater detail below in connection with FIGS. 19-26 and Tables 8 through 32. However, it should be appreciated that the present disclosure is not limited to the specific business rules discussed herein. For example, a business rule engine (not shown) may be used to allow business users to dynamically modify existing business rules at run time.

In applying the business rules 2240 to assess the work orders 2235A-C, the ticket assessment engine 2230 may rely on auxiliary input information such as facility plats, past damage reports, excavator history, traffic, weather, and the like. These pieces of information may be accessed as needed from an auxiliary information storage 2250, which may include one or more databases and/or lookup tables. Examples of various types of auxiliary input information used by the ticket assessment engine 2230 are described in greater detail below in connection with FIGS. 16-18.

In the embodiment shown in FIG. 12, the ticket assessment engine 2230 populates each of the work orders 2235A-C with corresponding assessment outcomes, such as a complexity reason code, an estimated duration, a risk score, an estimated value and/or skill or certification requirements. The populated work orders may then be forwarded to any number of components in the ticket management system 2200. For example, the populated work orders may be forwarded to a scheduling and dispatch application 2260, which may allocate an appropriate technician to each work order based on at least some of the assessment outcomes, such as estimated duration, estimated value and/or skill requirements. Alternatively, the populated work orders may be stored in a database that can be accessed by one or more components in the ticket management system 2200.

It should be appreciated that the ticket assessment engine 2230 may be implemented in any suitable manner, as the present disclosure is not limited in this respect. In some embodiments, the ticket assessment engine 2230 may be implemented using Windows Workflow Foundation (WF), which is a Microsoft® technology for defining, executing, and managing workflows. For example, a workflow definition may be loaded for assessment from a WF script, which specifies rules loaded from a rules file. When a new ticket is ready for assessment, a new instance of the workflow may be instantiated in a new WF thread. At the completion of successful ticket assessment, the assessment runtime may update the system database with the calculated output and mark the ticket as ready for scheduling.

The ticket assessment outcomes may be used by the scheduling and dispatch application 2260 in any suitable manner, as the present disclosure is not limited in this respect. In some embodiments, a value assessment outcome may be used as a weighting factor. For example, a ticket that is assessed as having high value may be weighted to encourage the scheduling and dispatch application 2260 to dispatch the ticket ahead of other tickets that are assessed as having lower values. A risk assessment outcome may be used in a similar fashion, to encourage the dispatch of higher
risk tickets ahead of lower risk tickets. This may provide for more opportunities for review and quality assessment for the higher risk tickets.

In some further embodiments, a skill requirements assessment outcome may be used by the scheduling and dispatch application 2260 as a constraining factor in assigning technicians to tickets. For example, a ticket may be assed as requiring a gas-certified, skill level 4 (GAS/4) locate technician. This may be used as a hard constraint, so that only locate technicians with GAS/4 or higher certification may be assigned to the ticket. Alternatively, the skill attribute may be used as a soft constraint, so that the ticket may be assigned to a lesser qualified locate technician only if a locate technician with GAS/4 or higher certification is not available. In such a situation, appropriate business rules may be implemented by the scheduling and dispatch application 2260 to determine whether any potential negative effects (such as increased risk, increased duration, and/or decreased profitability) are outweighed by the potential benefits of completing the requested location operation earlier.

When a technician reports the completion of a work order, the scheduling and dispatch application 2260 may forward the work order to a quality control application 2270, along with any activity logs and/or technician reports. The quality control application 2270 may determine whether the work order has been adequately responded to, for example, by checking the activity logs to determine whether every facility type listed on the work order is accounted for. The quality control application may also be programmed to present a user interface through which human supervisors may review the completed work orders and determine whether the technician is in need of additional training in any particular area.

The scheduling and dispatch application 2260 may also forward the completed work order to a billing application 2280, which may apply various billing rules to calculate a fee to be billed to each customer. For example, the billing application may use the activity logs to determine the amount of time the technician spent on each facility type and compute a fee accordingly to be billed to that facility owner.

In some embodiments, the ticket assessment system 2200 may further include a feedback mechanism, such as a backend assessment module 2290. As shown in FIG. 12, the backend assessment module 2290 may monitor completed work orders received from the scheduling and dispatch application 2260 and send appropriate updates to various other components of the ticket management system 2200. For example, the backend assessment module 2290 may maintain statistical information regarding the completed work orders and provide the statistical information to a business rule engine (not shown), which may update the business rules 2240 accordingly. Similarly, the backend assessment module 2290 may provide updates to some of the historical information stored in the auxiliary information storage 2250.

In some instances, a work order may be closed by a technician for reasons other than having completed the requested location operation. For example, the technician may be unable to gain access to a work site, or may discover significant discrepancy between the dig area description and the actual dig area. The technician may then close the current work order and request that a new work order be generated. Upon detecting such a situation, the backend assessment module 2290 may generate an appropriate new work order, e.g., with more accurate work site and/or dig area information, and submit it to the scheduling and dispatch application 2260 for re-dispatch.

Additionally, the backend assessment module 2290 may be adapted to receive information from the quality control application 2280. For example, upon reviewing a completed work order via the quality control application 2280, a human supervisor may discover a significant problem and may determine that a re-mark or re-stake operation is necessary. This information may be provided to the backend assessment module 2290, which may generate a new work order accordingly and perform appropriate updates to the information stored in the auxiliary information storage 2250.

3. Exemplary Locate Request Ticket

FIG. 13 shows an example of a locate request ticket 2300 that may be received by the ticket management system 2200, for example, via email from the one-call center 120 shown in FIG. 1. The ticket 2300 may contain various pieces of information stored in a number of fields, including:

- ticket number 2302,
- location information 2304A (e.g., address and nearby cross streets) and 2304B (e.g., lat/long coordinates),
- excavation information 2308, including reason (e.g., installing conduit), scope (e.g., 392 feet), depth (e.g., 18-30 inches), method (e.g., by drill and trencher) and property type (e.g., private property),
- timing information 2308, including scheduled excavation time (e.g., Jan. 6, 2008 at 7:00 a.m.) and duration (e.g., 3 days) and due date for the corresponding locate operation request (e.g., Jan. 5, 2008),
- excavator information 2310, including name, address, contact information such as phone number, fax number and email address, and the party who contracted the excavator (e.g., as indicated in the “Work Being Done For” field),
- one-call center information 2312, including the time at which the ticket was created and the customer service representative who created the ticket, and
- member codes 2314, indicating the different types of facilities that need to be located.

It should be appreciated that the above list of information elements is merely illustrative, as other combinations of information elements may also be suitable. For example, when preparing a locate request ticket, a one-call center may draw a polygon on a map corresponding to the work site. This polygon may be overlaid onto one or more facility maps to determine which types of facilities are implicated. For example, a facility type (or owner) may be indicated on the locate request ticket in the member code section 2314 if and only if at least one utility line of that type (or owner) touches or intersects with the polygon. In some instances, the one-call center may provide the coordinates for the vertices of the polygon in the locate request ticket, along with other information describing the location and boundaries of the work site and/or dig area.

In some embodiments, one or more images or graphical representations of the work site and/or dig area may be attached to the ticket 2300. For instance, a so-called virtual white lines (VWL) image may be attached, which may contain a digital image of the work site including the dig area (or some other suitable digital data representing the geographic location of the dig area) along with electronic annotations delimiting the dig area.

An example of a VWL image 2400 is shown in FIG. 14. As shown, the dig area is indicated on an aerial image by a set of dashed lines 2410 forming a rectangle. The lines 2410 are more generally referred to as “virtual white lines,” which may be any electronically generated markings indicating a point, line, path and/or area of the planned excavation.

In some embodiments, the VWL image 2400 may be created by the excavator using a suitable VWL application.
(not shown), such as those described in U.S. patent application Ser. No. 12/050,555 and U.S. Provisional Patent Application No. 61/151,769 and No. 61/151,815, all of which have been incorporated by reference herein in their entirety. For example, the excavator may use the VWL application to obtain an aerial image of a geographical location encompassing the planned dig area and use a drawing tool of the VWL application to add the VWL 2410 to the aerial image.

4. Ticket Parsing

As discussed above, locate request tickets originating from different one-call centers may store information in different formats (e.g., different one-call centers may use different commercial software to generate locate request tickets). Therefore, a ticket parsing application, such as the ticket parser 2210 shown in FIG. 12, may be used to convert incoming tickets to a standardized format recognized by various components within a ticket management system.

FIG. 15 shows an illustrative process 2500 that may be performed by a ticket parsing application to convert an incoming locate request ticket into a parsed ticket.

At act 2502, the ticket parsing application may identify a source or origin of the incoming ticket (e.g., a particular one-call center that generated the incoming ticket). This may be accomplished in a number of different ways. For example, the ticket parsing application may simply search the ticket to determine whether the originating one-call center is identified in the ticket itself. Alternatively, if the ticket is received via email, the ticket parsing application may identify the originating one-call center by examining the sender’s email address. As yet another example, the ticket parsing application may search the ticket for some indication of a geographic area to which the work site belongs (e.g., a city or town name) and identify a one-call center serving that geographic area.

At act 2504, the ticket parsing application may retrieve or otherwise identify a set of parsing rules corresponding to the one-call center identified at act 2502. The parsing rules may allow the ticket parsing application to detect the locations of various fields within the incoming ticket. In some instances, there may be a fixed ordering among the various fields, and each field may be a text block of a fixed length. Thus, each field or text block may be found at a corresponding fixed offset from the beginning of the incoming ticket. Alternatively, some of the fields may have variable lengths, and one or more designated markers may be used to demarcate the end of a field (or the beginning of the next field). In that case, the ticket parsing application may locate and process the various fields in a sequential fashion.

At acts 2506 and 2508, the ticket parsing application may identify a text block that has not been processed and proceed to extract information from the identified text block. For example, for a text block corresponding to an address field, the ticket parsing application may simply copy the entire string from the text block. Some minor transformations may be performed at act 2510, such as truncating a street name that exceed a predetermined maximum length. More significant transformations may also be performed. For example, the ticket parsing application may be programmed to recognize alphanumeric codes and/or abbreviations specific to each one-call center and map those codes and/or abbreviations to some suitable standard representations.

At act 2512, the ticket parsing application may populate appropriate fields in the parsed ticket with the information obtained at acts 2506 and 2508. Then, at act 2514, the ticket parsing application may determine whether there are any unprocessed text blocks in the incoming ticket. If the determination is positive, the ticket parsing application may return to act 2506 to identify a next unprocessed text block. Otherwise, the ticket parsing application may end the process 2500, and the parsed ticket may be forwarded to a ticket assessment engine for further processing and analysis.

It should be appreciated that the process 2500 for parsing an incoming ticket is merely illustrative. Depending on the one-call centers’ actual practices, other processes and methods may also be suitable for converting an incoming locate request ticket to a standardized format.

5. Auxiliary Information Sources

As discussed above in connection with FIG. 12, the ticket assessment engine 2230 may access various types of auxiliary information from the auxiliary information storage 2250 in order to produce the desired assessment outcomes. For example, as shown in FIG. 16, the assessment engine 2230 may retrieve one or more images 2605 from the auxiliary information storage 2250, along with associated metadata (e.g., geospatial metadata). As described in greater detail below, the stored images 2605 may be created or modified by a geographic information system (GIS) 2610 based on one or more input images 2615.

For purposes of the present disclosure, an input image 2615 may be represented by any source data that, when processed electronically by a suitable computer system, enables the computer system to display an image on a display device. This source data may be in any of a variety of suitable computer-readable formats, including PDF, JPG, BMP, GIF, PNG and the like.

In some instances, the source data for an image may be generated by scanning a tangible two-dimensional image source, such as paper or cloth. Alternatively, the source data may be generated by an image acquisition device as the result of acquiring a “real-world” scene. Examples of an image acquisition device include a digital camera (either still-frame or video), which may generate pixel information as part of the source data for an image. An image acquisition device may also be a laser scanning device that scans three-dimensional objects to produce coordinate information in a three-dimensional space.

The following is a non-exhaustive list of exemplary input images (or source data) using which the GIS 2610 may create or modify the stored images 2605:

- Manual “free-hand” paper sketches of a geographic area, which may include one or more buildings, natural or man-made landmarks, property boundaries, streets, intersections and/or public works or facilities such as street lighting, signage, fire hydrants, mail boxes, parking meters, etc.
- Various maps indicating surface features and/or extents of geographical areas, such as street maps, topographical maps, military maps, parcel maps, tax maps, town and county planning maps, polygon maps maintained by one-call centers and/or facility owners, virtual maps, etc.
- Facility maps illustrating installed underground facilities, such as gas, power, telephone, cable, fiber optics, water, sewer, drainage, etc. Street-level features or landmarks (e.g., streets, buildings, aboveground facilities, etc.) may also be indicated in relation to the depicted underground facilities.
- Facilities maps may be provided in paper and/or electronic form and may be maintained by, for example, one or more facility owners. For example, a gas company may maintain maps of gas lines, a power company may maintain maps of power lines, and so on.
- Architectural, construction and/or engineering drawings and virtual renditions of a space/geographic area, including “as built” and/or post-construction drawings.
Land surveys, which are plots produced at ground level using references to fixed points such as the center line of a street to indicate the metes and bounds of a building, parcel, utility, roadway, or other object or installation, as well as other related location data.

Photographic renderings/images, including street level, topographical, satellite, and aerial photographic renderings/images, any of which may be updated periodically to capture changes in a given geographic area over time (e.g., seasonal changes such as foliage density, which may variably impact the visibility of some features in the geographic area).

A grid (e.g., a pattern of horizontal and vertical lines) used as a reference to provide representational geographic information, which may be added as an overlay to an acquired "real world" scene, a drawing, a map, etc.

"Bare" data representing geo-encoded information (e.g., lat/long coordinates identifying one or more points), which may be used to construct a virtual image without having captured any "real-world" scene. Such "bare" data may be in any of a variety of computer-readable formats, including XML.

In accordance with some embodiments, input images or source data such as those listed above may be analyzed and/or manipulated by the GIS 2610 shown in FIG. 16. For example, the GIS 2610 may be programmed to "geotag" an input image by associating geospatial metadata with features in the input image. The geospatial metadata may include any suitable combination of lat/long coordinates, altitude, bearing, place names, etc. As another example, the GIS 2610 may be programmed to create a computer-aided design (CAD) drawing showing aboveground and/or underground facilities installed in a geographic area, and to associate geospatial metadata with at least some of the facilities shown on the drawing. As yet another example, the GIS 2610 may be programmed to align two geotagged images, for example, by scaling one or both of the images and aligning one or more reference points. This process is sometimes referred to as "georeferencing," and may be useful in combining one or more facility maps showing different types of facilities installed in the same geographic area.

Thus, the GIS 2610 may provide a framework for manipulating and displaying images in ways that may facilitate a variety of location-related analyses. As shown in FIG. 16, the ticket assessment engine may be adapted to invoke one or more services provided by the GIS 2610. For example, the assessment engine may submit a geotagged VVL image (e.g., the VVL image 2400 shown in FIG. 14) to the GIS 2610 and request that the VVL (e.g., the VVL 2410) be shown on a facility map. Upon receiving the request, the GIS 2610 may obtain a relevant facility map, for example, by retrieving one or more existing maps from the auxiliary information storage 2250 and combining them if necessary, or by creating a CAD drawing showing all facilities known to be present in the geographic area shown on the VVL image 2400. The GIS 2610 may then render the VVL 2410 as an overlay on the facility map based on the geospatial metadata associated with the VVL image and the facility map. An example of the resulting facility map 2700 with the VVL 2410 is shown in FIG. 17.

Images are merely one example of a variety of different types of information that may be used by a ticket assessment engine. Another example is a set of lookup tables, such as the lookup tables 800 shown in FIG. 18. In accordance with some embodiments, the ticket assessment engine may load one or more of these lookup tables and use them to map locate operation attributes to intermediate or final assessment outcomes. The locate operation attributes may be raw attributes directly obtained from locate request tickets, or derived attributes assigned by the ticket assessment engine based on some raw attributes.

In the exemplary embodiment shown in FIG. 18, the lookup tables 2800 include a complexity lookup table 2810, a duration lookup table 2820, a risk lookup table 2830, a value lookup table 2840 and a skill level lookup table 2850.

The complexity lookup table 2810 may be used to assign a suitable measure of complexity to a requested locate operation, and may be indexed with a variety of different locate operation attributes. For example, the complexity look up table 2810 may map the number of facilities to be located and/or each individual facility type (e.g., gas, cable, electric, water, etc.) to a suitable complexity level (e.g., high, medium or low). As another example, the complexity lookup table 2810 may map work site details such as high traffic or restricted access to corresponding complexity reason codes that are recognized by various components within a ticket management system (e.g., the ticket management system 2200 shown in FIG. 12).

Similar to the complexity lookup table 2810, the duration lookup table 2820 and the risk lookup table 2830 may be used, respectively, to assign an estimated duration and a suitable measure of risk to a requested locate operation. For example, the duration look up table 2820 may map each individual facility type (e.g., gas, cable, electric, water, etc.) to a duration estimate per unit length or unit area, and the risk lookup table 2830 may map each individual facility type to a suitable risk score. Additionally, the duration lookup table 2820 and the risk lookup table 2830 may, respectively, map work site details such as high traffic or restricted access to corresponding scaling factors for increasing or decreasing a duration estimate and a risk score.

The value lookup table 2840 may be used to associate a value to a requested locate operation. The value may be simply the expected revenue to be collected for the work performed, or some other suitable measure of value such as net profit (e.g., revenue less cost) or value at risk. In some embodiments, the value lookup table 2840 may correlate complexity with value (e.g., mapping high complexity to high value, medium complexity to medium value, and low complexity to low value), where the complexity level is determined at least in part using the complexity lookup table 2810. In some further embodiments, the value lookup table 2840 may map each individual facility type (e.g., gas, cable, electric, water, etc.) to a value estimate, which may be a flat rate or a rate per unit length. In yet some further embodiments, the value lookup table 2840 may map ticket types (e.g., emergency, short notice, re-mark, etc.) to corresponding adjustment values for increasing or decreasing a value. For example, extra fees may be collected for an emergency locate operation, while a re-mark operation may not be billed to a customer if the locate service provider is at fault (e.g., the locate service provider did not adequately respond to the locate request ticket during a first visit, which was already billed to the customer).

The skill level lookup table 2850 may be used to determine any technician certification and/or minimum skill level requirements for a requested locate operation. For example, locate technician skill levels may be ranked from 1-10, with 10 being the most skilled. The skill level lookup table 2850 may map high complexity to skill levels 8-10, medium complexity to skill levels 4-7, low complexity to skill levels 1-3, where the complexity level is determined at least in part using the complexity lookup table 2810. As another example, the skill level look up table 2850 may map each
individual facility type (e.g., gas, cable, electric, water, etc.) to one or more technician certifications (e.g., gas-certified, cable-certified, electric-certified, water-certified, etc.).

It should be appreciated that the set of lookup tables 2800 is provided herein for purposes of illustration only. For example, although lookup tables may provide quick access to data, other types of data structures may also be used to store the information contents described above. Also, a ticket assessment engine may access other types of information contents in addition to, or instead of, those described above. For example, in determining a risk level associated with a requested locate operation, a ticket assessment engine may access historical records of previously completed locate request tickets to determine whether there is a high concentration of past damage reports within the proximity of the currently requested locate operation.

At act 2902, the ticket assessment engine may access records pertaining to excavation companies and/or individual excavators. Such records may contain information such as excavation company name and address, individual excavator name and address, excavator type (e.g., pool installer, landscaper, construction company, facility installer, etc.), and/or damage history. In some embodiments, a ticket assessment engine may use the excavator type information and the damage history information to assess the level of risk associated with a currently requested locate operation. For example, the ticket assessment engine may return a high risk classification for a requested locate operation when a corresponding excavation company and/or individual excavator has a significant history of damaging facilities. The ticket assessment engine may further increase a technician skill level requirement for the requested locate operation, as a way to ensure accurate marking and reduce risk.

6. Location Assessment

As discussed above, location information provided in a locate request ticket may in some instances be incomplete and/or inaccurate. For example, the address for the work site may be vague or ambiguous (e.g., a street name without any house numbers), or multiple conflicting pieces of location information may be given (e.g., a street address and a pair of lat/long coordinates that do not match). In these situations, additional analysis may be needed to increase the level of confidence that a locate technician is being dispatched to the correct location.

FIG. 19 shows an illustrative process 2900 that may be performed by a ticket assessment engine to select the best available location information and refine the location information when necessary.

At act 2904, the ticket assessment engine may select a piece of location information from the multiple pieces of location information collected at act 2902. This selection may be based on levels of confidence, that is, the ticket assessment engine may select the piece of location information that is deemed the most trustworthy or reliable. In some embodiments, a geotagged VVL image may be considered the most reliable among all types of location information. As such, it may be selected whenever available. If a geotagged VVL image is not available, then a complete address (e.g., with city, street name and house number) may be selected over other pieces of location information, such as a one-call center polygon. If neither a geotagged VVL image nor a complete address is available, then coordinates for the centroid of a one-call center polygon may be computed and reverse-geocoded to obtain an address.

The ticket assessment engine may also perform one or more consistency checks on the collected location information. For example, the ticket assessment engine may reverse-geocode at least some of the available coordinates to determine if the coordinates correspond to a point that falls within the city, county, and/or state indicated on the ticket.

At act 2906, the ticket assessment engine may determine whether the location information selected at act 2904 has a sufficiently high confidence level. If the determination is positive, then the process 2900 ends and the selected location information may be recorded and used throughout the rest of the assessment process carried out by the ticket assessment engine. If the determination is negative, the ticket assessment engine may make a best-effort attempt at refining the location information at act 2908.

FIG. 20 illustrates an exemplary method for refining location information. In this example, a street name (e.g., "Main Street") is available, but without a house number. A one-call center polygon 21000 is also available. The ticket assessment engine may programmed to determine the coordinates for the points 21005A and 21005B, at which Main Street intersects the one-call center polygon 21000. These coordinates may then be reverse-geocoded to obtain an address range on Main Street that falls within the one-call center polygon 21000. If the address range is sufficiently small, the ticket assessment engine may simply select the address range as the prevailing location information. If, however, the address range is too large, the ticket assessment engine may narrow it down by computing the centroid of the one-call center polygon 21000 and selecting one or more addresses 21005C that are closest to the computed centroid.

It should be appreciated that the various rules and methods described above in connection with FIGS. 19 and 20 are merely illustrative, as other rules and methods may also be used to select, verify and/or refine location information. Also, the ticket assessment engine may invoke the services of a geographic information system (e.g., the GIS 2610 shown in FIG. 16) to perform any of the computational tasks described above.

7. Scope Assessment

In assessing the scope of a locate request ticket, a ticket assessment engine may determine the nature and amount of work to be done in response to the ticket. The result of scope assessment may be used in a number of subsequent assessment processes, such as complexity, duration, risk, value and/or skill requirements. For example, during scope assessment, the number and types of facilities to be located may be determined or verified, which may in turn be used to determine complexity (e.g., whether a high profile facility type is involved), duration (e.g., an estimated duration for each facility type), risk (e.g., whether a high risk facility,
such as gas, is involved), value (e.g., an estimated revenue to be collected for each facility type) and/or skill requirements (e.g., certification requirements for each facility type).

In some instances, a one-call center may compile some form of ticket scope information and include the information in a locate request ticket. For example, a one-call center may generate a polygon and determine, based on the polygon, which facility types are to be listed on the ticket. However, such information from one-call centers may not always be accurate, and therefore it may be desirable to independently generate and verify ticket scope information.

FIG. 21 shows an illustrative process 21100 that may be performed by a ticket assessment engine to assess the scope of a locate request ticket.

At act 21102, the ticket assessment engine may extract various pieces of information from the ticket to determine the bounds of the planned dig area. For example, if a geotagged VWL image is available, the ticket assessment engine may determine the dig area boundaries based on the VWL and the geospatial metadata associated with the VWL image. As discussed above, the ticket assessment engine may associate a higher level of confidence to the VWL image, compared to a polygon generated by the one-call center. Therefore, in some embodiments, the VWL image may be used in lieu of the one-call center polygon in determining ticket scope.

The ticket assessment engine may also use other types of information during act 21102. In some embodiments, the ticket assessment engine may search for scope information in one or more free text portions of the ticket. For example, the ticket assessment engine may be programmed to search for keywords related to landmarks (e.g., sidewalk, playground, etc.) and/or directions (e.g., north, east, south, west, etc.). If one or more keywords are found, the ticket assessment engine may prompt a human user to read the free text and enter any additional scope information.

At act 21104, the ticket assessment engine may determine the reason for excavation, which may be used to determine other scope-related parameters such as excavation depth.

The reason for excavation may sometimes be given explicitly in the ticket. For example, as shown in FIG. 13, the ticket 2300 may indicate under the excavation information 306 and the excavator information 2310 that a conduit is being installed for a telephone company. In other situations, the reason for excavation may be found in a free text description given by the excavator, and the ticket assessment engine may search for informative keywords or key phrases in the free text description. For example, words such as “pool” and “mailbox” may be commonly used when describing the reason for excavation, and the ticket parsing application may be programmed to search for these words and extract relevant portions of the free text.

At act 21106, the ticket assessment engine may determine or verify the number and types of facilities to be located. As discussed above, it may be desirable to independently verify this information, even though it may be already provided by the one-call center.

The ticket assessment may use a variety of auxiliary information (e.g., as stored in the auxiliary information storage 2250 shown in FIG. 12) in determining or verifying the number and types of facilities to be located. For example, the ticket assessment engine may access one or more facility maps illustrating installed underground facilities and street-level landmarks. In some instances, the facility maps may be geotagged, which may enable overlaying a polygon or VWL onto the facility maps (e.g., as shown in FIG. 17) to determine whether one or more items on the facility maps fall within the dig area or are sufficiently close to the dig area.

Continuing to act 21108, the ticket assessment engine may determine scope information for each individual facility type determined at act 21106. For example, the ticket assessment engine may compare the dig area boundaries (e.g., as indicated by a VWL or a polygon) against a respective facility map. This may facilitate subsequent duration estimation (e.g., different facility types may have different duration estimates per unit length or unit area). It may also facilitate billing after the ticket has been completed (e.g., some facility owners may be billed on a per ticket basis, while other facility owners may be billed per unit of work performed).

8. Complexity Assessment

In various embodiments, a ticket may be considered more or less complex for a number of different reasons, such as the number and types of facilities to be located, work site characteristics and/or some other suitable factors. Therefore, complexity assessment may very broadly encompass any types of analysis to categorize and/or annotate a ticket in such a way that facilitates subsequent handling of the ticket. For example, the outcomes of complexity assessment may be presented in any suitable manner (e.g., using numerical scores and/or user-defined categories), and may inform any other assessment process, such as duration, risk, value or skill requirements.

FIG. 22 shows an illustrative process 21200 that may be performed by a ticket assessment engine to assess the complexity of a locate request ticket, in accordance with some embodiments.

At act 21202, the ticket assessment engine may perform a keyword search on the ticket to look for any keywords that may trigger a complexity designation. For example, service contracts with some facility owners may include special requirements for the handling of certain “high profile” facilities (e.g., fiber optic cables). A locate service provider may also have internal regulations designating certain facilities as being “high profile.” This may be done, for example, for risk management purposes. Thus, when the ticket assessment engine detects the presence of one or more high profile facility names (e.g., gas or fiber optic), the ticket may be put into a complexity category of “high profile.” Additionally, one or more reason codes and/or descriptions may be given to indicate why the ticket was been categorized under “high profile.”

Then, at act 21204, the ticket assessment engine records the complexity category assigned to the locate request ticket during act 21202, along with any reason codes and/or descriptions. This recording may be done in any suitable manner that allows the assigned complexity category to be later accessed using some information associated with the ticket. For example, the ticket assessment engine may store the assigned category in a database entry that can be indexed using a ticket serial number. Alternatively, the ticket assessment engine may insert the assigned complexity category into a work order created for the ticket (e.g., work orders 2235A-C shown in FIG. 12).

At act 21206, the ticket assessment engine may determine whether the work site falls within some complexity region. For example, the ticket assessment engine may access a data storage (e.g., the auxiliary information storage 2250) to obtain a set of polygons representing, respectively, a set of predetermined complexity regions. Each of the polygons may be specified by the set of coordinates for its vertices, and may be associated with a complexity category indicating
why the region has been designated as a complexity region. A description of the complexity category may also be provided.

The ticket assessment engine may then geocode an address of the work site and determine whether the resulting coordinates fall within any of the complexity regions represented by the polygons. If the coordinates do fall within at least one complexity region, the ticket assessment engine may proceed to act 21208 to store the corresponding complexity category and/or complexity category description.

It should be appreciated that the polygons representing complexity regions may be generated in a number of different ways, as the present disclosure is not limited in this respect. For example, a geographical information system (e.g., the GIS 2610 shown in FIG. 16) may be used to analyze one or more facility maps, either alone or in combination, to identify any geographical area with a high concentration of underground facilities. As another example, some commercially available digital map data may contain information delineating various geographical regions of interest, such as highways, parks, hospitals, military bases, parks, etc. A geographical information system may be used to automatically assign complexity categories to some of these regions. The corresponding delineation information may then be extracted from the digital map data and used to compute polygons.

Additionally, a geographical information system may be adapted to allow a human user to manually define a complexity region. For example, a supervisory personnel may, based on local knowledge, designate a certain geographic area as a complexity region and provide an appropriate description (e.g., the area may be known to have defective tracer wires along a certain type of facility, which may increase the difficulty in locating that type of facility). The geographical information system may present a graphic user interface to allow the supervisory personnel to electronically mark the boundaries of the complexity region.

Returning to FIG. 22, the ticket assessment engine may determine at act 21210 whether the work site is in the proximity of a past ticket categorized as “high profile.” For example, the ticket assessment engine may search a database of past tickets to determine whether the work site is within a given radius (e.g., 100 yards) of a past ticket with a “high profile” designation. If so, the ticket assessment engine may assign the complexity category “high profile potential” to the current ticket and record a reason code “historical high profile” at act 21212.

At act 21214, the ticket assessment engine may determine whether the locate request ticket is subject to special billing rules. For example, the ticket assessment engine may determine whether the ticket has a linear scope of 0.5 miles or greater (e.g., as determined during the scope assessment process 21100), or whether the work site is at a remote location that requires extended travel. Additionally, the ticket assessment engine may search one or more text fields (e.g., locate instructions, remarks and/or excavation type description) for keywords that might be relevant for billing. Then the ticket assessment engine may consult one or more billing tables to determine whether any special billing rules apply to the current ticket. For example, at act 21216, the ticket assessment engine may set a hourly status indicator to “true,” indicating that the ticket should be billed per unit of work performed, rather than at a flat rate.

It should be appreciated that the billing tables used by the ticket assessment engine may contain information that is specific to a particular geographic area. For example, different facility owners serving different geographical areas may be billed at different rates using different methods. Therefore, multiple billing tables may be prepared and selected for use based on the geographic areas in which the locate service provider is operating.

Proceeding to act 21218, the ticket assessment engine may determine a service type (e.g., “emergency,” “short notice,” “re-mark,” “re-stake,” or “remote”) by performing a keyword search. The search may take into account common abbreviations such as “short.” If a relevant keyword is found, the ticket assessment engine may record the corresponding service type at act 21220. This information may be used, for example, during the scheduling and dispatch process to determine a due date or deadline for the ticket. It may also be used in determining an appropriate fee to be billed to a customer.

As discussed in connection with FIG. 12, some of the above-described functionalities relating to complexity assessment may be expressed via a set of business rules (e.g., one or more of business rules 2240 shown in FIG. 12). An exemplary set of complexity assessment business rules is summarized in Table 1 below (BR-001 through BR-005) and described in greater detail in Tables 9-13.

9. Duration Assessment

In some embodiments, the duration of a locate request ticket (i.e., the amount of time worked by a locate technician to complete the requested locate operation) may be estimated using statistical information collected from previously complete locate request tickets. For example, a ticket assessment engine may access a historical average and/or standard deviation for tickets of a certain type (e.g., tickets having a certain combination of features). This information may then be used to establish an offset and/or scaling factor to be applied to future tickets of the same type (e.g., having the same combination of features).

FIG. 23 shows an illustrative process 21300 that may be performed by a ticket assessment engine to estimate the duration of a locate request ticket, in accordance with some embodiments.

At act 21302, the ticket assessment engine may establish an initial duration estimate, for example, based on the total number of facilities to be located (e.g., as determined or verified during the scope assessment process 21100). More specifically, if the ticket is an N-locate ticket (i.e., there are N different types of facilities to be located), the ticket assessment engine may obtain the historical average duration for all previously complete N-locate tickets. Alternatively, the ticket assessment engine may obtain the standard deviation in addition to the average, and determine a duration estimate such that, with high probability, at least a desired percentage (e.g., 95 percent) of all N-locate tickets will have a duration not exceeding the duration estimate. Such an estimate may be computed using any known techniques, such as Chebyshev’s inequality.

At act 21304, the ticket assessment engine may, based on a number of different factors, determine on or more offsets to be applied to the initial duration estimate established at act 21302. For example, an offset may be assigned to each facility type based on observed averages. More specifically, if an N-locate ticket having a first facility type (e.g., gas) is on average 4 minutes longer than an N-locate ticket not having the first facility type, then an offset of 4 minutes may be assigned to the facility type “Gas.” On the other hand, if an N-locate ticket having a second facility type (e.g., sewer) is on average 3 minutes shorter than an N-locate ticket not having the second facility type, then an offset of −3 minutes may be assigned to the facility type “Sewer.”
As another example, an offset may be determined based on complexity region type (e.g., as determined at act 21206 shown in FIG. 22). More specifically, it may have been observed that an average ticket having a complexity region type “Gated” (e.g., the work site is within a gated community requiring some form of access approval, such as an access code) is 15 minutes longer than an overall average. Then an offset of 15 minutes may be assigned to all tickets having a complexity region type “Gated.” Alternatively, an appropriate offset may be chosen to guarantee that, with high probability, all tickets with complexity region type “Gated” will have a duration not exceeding the average duration plus the offset. Such an offset may be chosen using any known techniques using standard deviation information.

Similarly, offsets may be determined for other complexity region types, such as military base (e.g., 35 minutes, due to strict verification procedures for access permits) and/or regions with aerial power lines (e.g., ~10 minutes, because aerial power lines may be located without special equipment).

At act 21306, various scaling factors may be established for the duration estimate. For example, if a ticket is determined to be high profile with a reason code (e.g., as in act 21202 shown in FIG. 22), the reason code may be used to index an appropriate scaling factor. In some embodiments, the scaling factor may be 1.15 for a high profile ticket with no reason code given, 1.38 for the reason code “Fiber Optic,” and 1.23 for reason code “HCPHONE” (or high capacity phone line).

A similar, but not necessarily identical, set of scaling factors may be chosen for tickets with high profile potential under reason code historical high profile (e.g., as determined in act 21210 shown in FIG. 22). For example, the scaling factors for no reason code, reason code “Fiber Optic” and reason code “HCPHONE” may be, respectively, 1.08, 1.3 and 1.18.

Other complexity designations may also be used to establish scaling factors. For example, if a ticket’s hourly status indicator is set to “true” (e.g., as in act 21214 shown in FIG. 22), the corresponding duration estimate may be scaled based on an estimated size of the dig area (e.g., in length or in area). More specifically, the scaling factor may be obtained by dividing the length of the dig area by a base value (e.g., 0.5 miles), or by dividing the size of the dig area by a base value (e.g., 10000 square feet). Similarly, the size type of a ticket (e.g., as determined in act 21218 shown in FIG. 22) may be used to look up a corresponding scaling factor, such as 1.23 for emergency and 1.82 for short notice.

It should be appreciated that all of the scaling factors may be determined based on average and/or standard deviation information using techniques similar to those described above for establishing offsets. Other techniques may also be possible, such as manual optimizations.

Proceeding to act 21308, any offsets determined at act 21304 and scaling factors determined at act 21306 may be applied in a suitable manner to the initial duration estimate determined at act 21302. For example, all offsets may be applied (e.g., added to the duration estimate), and then all scaling factors may be applied (e.g., multiplied with the duration estimate). Other methods may also be possible, such as breaking down the duration estimate into different components (e.g., one for each facility type) and applying appropriate offsets and/or scaling factors to the individual components, in addition to, or instead of applying offsets and/or scaling factors to the overall duration estimate.

As with complexity assessment, some of the above-described functionalities relating to duration assessment may be expressed via a set of business rules (e.g., one or more of business rules 2240 shown in FIG. 12). An exemplary set of duration assessment business rules is summarized in Table 8 below (BR-006 through BR-012) and described in greater detail in Tables 14-20.

10. Risk Assessment

In some embodiments, the risk associated with a locate request ticket may be represented as a numerical score (e.g., a number between 1 and 100) or a broad category (e.g., high, medium or low). As discussed in greater detail below, the score or category may be determined based on historical data, such as the frequency and extent of damage among a certain class of previously completed tickets. This risk measure may be used to flag some of the incoming tickets for special consideration and/or handling. For example, it may be required that a high risk ticket be handled only by a technician with a high level of skill. Alternatively, or additionally, a high risk ticket may require supervisory review after completion, to check for any errors that may have been made by the technician performing the requested locate operation.

FIG. 24 shows an illustrative process 21400 that may be performed by a ticket assessment engine to compute a risk measurement (e.g., a numerical score or category) associated with a locate request ticket, in accordance with some embodiments.

At act 21402, a risk score may be established for each facility type to be located. For example, gas, electric and water may be assigned a risk score of 2.5, 0.7 and 0.2 respectively. These scores may be determined based on a number of different factors, such as the frequency of damages related to a facility type (e.g., the percentage of gas locates that resulted in damage reports) and the extent of damages related to a facility type (e.g., the average monetary value of claims resulting from damages to gas pipes). Finer distinctions may also be made, such as assigning different risk scores based on attributes of facilities of the same type. For example, damages to water mains may result in very high claim amounts (e.g., streets may collapse due to a ruptured water main), while damages to water lines leading a customer’s premise may be minor and easy to repair. As another example, the diameters of gas pipes may be taken into account, where thicker pipes may be associated with lower gas pressure and may be more at risk for explosions.

At act 21404, the various risk scores determined at act 21402 may be summed to obtain an overall risk score for the ticket. Then, at act 21406, one or more appropriate scaling factors may be determined for adjusting the overall risk score. For example, the ticket assessment engine may access a database of past damage reports to determine whether the work site and/or dig area for the current ticket is within a given radius (e.g., 500 yards) of one or more past damage reports and, if so, computes the total amount of claims from all of the damage reports within this radius. This total amount may in turn be used to lookup an appropriate scaling factor for the risk score, for example, as shown in Table 22 below.

As another example, the ticket assessment engine may determine whether the excavator who submitted the excavation notice corresponding to the current ticket has a significant history of damages. This history can be measured in a number of different ways. For example, an average damage amount (e.g., in dollar value) per excavation (or locate operation) may be computed for at least some of the excavators for whom historical information is available. The
average may be computed over a certain time frame (e.g., the past six months, or one, two, three, five or ten years). The average across different excavators may also be computed. Then the ticket assessment engine may compare a particular excavator’s average damage amount against the average across all excavators, for example, by expressing the former as a percentage of the latter. This percentage may be used to look up a corresponding scaling factor for the overall risk score of the ticket (e.g., as shown in Table 23 below).

Alternatively, or additionally, a damage count (e.g., the number of damage reports irrespective of the dollar amount for each report) may be obtained for each excavator and compared against an average damage count across different excavators, for example, over a certain time frame (e.g., the past six months, or one, two, three, five or ten years). Again, a particular excavator’s damage count may be expressed as a percentage of the average damage count, and the percentage may be used to look up an appropriate scaling factor (e.g., as shown in Table 23 below).

Complexity designations such as high profile may also be used to determine one or more appropriate scaling factors for the overall risk score. For example, if a ticket is determined to be high profile with a certain reason code (e.g., as in act 21202 shown in FIG. 22), the reason code may be used to index an appropriate scaling factor. In some embodiments, the scaling factor may be 1.8 for a high profile ticket with no reason code given, 4.0 for the reason code “Fiber Optic,” and 2.5 for reason code “HFPhone” (e.g., as shown in Table 24 below).

As another example, if a ticket’s hourly status indicator is set to “true” (e.g., as in act 21214 shown in FIG. 22), the corresponding duration estimate may be scaled based on an estimated size of the dig area (e.g., in length or in area). In the embodiment described in Table 26 below, the scaling factor may be obtained by dividing the length of the dig area by a base value (e.g., 0.5 miles), or by dividing the area of the dig area by a base value (e.g., 10000 square feet). Similarly, the service type of a ticket (e.g., as determined in act 21218 shown in FIG. 22) may be used to look up a corresponding scaling factor, such as 2.85 for emergency, 3.46 for 2-hour short notice, and 3.11 for 3-hour short notice (e.g., as shown in Table 25 below).

11. Value Assessment

In some embodiments, the value is simply the revenue to be collected for performing the corresponding locate operation. However, it should be appreciated that other measures of value may also be possible, such as net profit (e.g., revenue less cost).

Additionally, value need not be restricted to monetary value. It may be any custom-defined value, or even a time-varying function. For example, as discussed above, the value estimate may be provided to a scheduling and dispatch application (e.g., the scheduling and dispatch application 2250 shown in FIG. 12), which may use the value estimate to prioritize activities. Thus, the value estimate may be used as a means to encourage a desired scheduling behavior. For example, if a ticket falls within a certain geographic area known to have heavy traffic during certain times of day, the value estimate may be defined as a function that has lower value during the periods of heavy traffic and higher values elsewhere. This may encourage the scheduling and dispatch application to avoid dispatching the ticket during the periods of heavy traffic.

Similarly, the ticket assessment engine may access an up-to-date source of weather information and define the value estimate as a time-varying function according to the weather forecast for the work site. For instance, the value estimate function may be defined in such a way that the scheduling and dispatch application is encouraged to avoid dispatching a technician to the work site in weather conditions that may hinder the locating and marking of underground facilities (e.g., rain or snow).

FIG. 25 shows an illustrative process 21500 that may be performed by a ticket assessment engine to compute an estimated value (e.g., expected revenue) for a locate request ticket.

At act 21502, the ticket assessment engine may determine if the ticket is a duplicate ticket, such as a re-mark, re-stake or re-note ticket. Under some service contracts, such tickets may not be billed if the re-mark, re-stake or re-note is necessitated due to some action, or lack of action, by the locate service provider. Additionally, some service contracts may specify that two tickets transmitted on the same day are duplicate tickets if the corresponding work sites are sufficiently close to each other, and that only one of the duplicate tickets may be billed.

If the ticket is determined to be a duplicate ticket, then the ticket assessment engine sets the revenue to zero at act 21504. Otherwise, the ticket assessment engine may determined the applicable billing method at act 21506, for example, whether the ticket should be billed at a flat rate, per unit of work performed, or per hour worked.

If the ticket is to be billed at a flat rate, the ticket assessment engine may proceed to act 1508 and consult a billing rate table to select an appropriate flat rate, for example, based on the type of facility located and/or the identity of the facility owner. Otherwise, the ticket assessment engine may proceed to act 21510 and determine an appropriate billing rate, which may be either per unit of work performed (e.g., unit length of facility marked, unit area of dig area located, or some other custom-defined unit of work) or per hour worked. Then the ticket assessment engine may proceed to act 21512 to obtain an estimated scope of the ticket (e.g., as determined during the process 21100 shown in FIG. 21) or an estimated duration of the ticket (e.g., as determined during the process 1300 shown in FIG. 23).

Based on the rate information and the scope or duration information, the ticket assessment engine may compute an estimated revenue amount for the ticket.

It should be appreciated that the process 21500 may alternatively be performed on a per facility type basis. That is, a revenue estimate may be determined for each facility type to be located using a process similar to the process 21500. Then the separate revenue estimates may be summed to obtain a total estimate for the ticket.

As with other types of assessment, some of the above-described functionalities relating to value assessment may be expressed via a set of business rules (e.g., one or more of business rules 2240 shown in FIG. 12). An exemplary set of value assessment business rules is summarized in Table 8 below (BR-019 through BR-022) and described in greater detail in Tables 26-29.

12. Skill Requirements Assessment

FIG. 26 shows an illustrative process 21600 that may be performed by a ticket assessment engine to specify one or more requirements for selecting a suitable technician to perform a requested locate operation. As discussed above, skill requirements may refer broadly to any suitable attributes of a technician, including experience level, past performance level (e.g., both long term and short term), certifications, and/or security clearance.

At act 21602, the ticket assessment engine may determine skill requirements based on the types of facilities to be
located. For example, a contract with a facility owner (e.g., gas) may require that only technicians with the appropriate certification (e.g., gas certification) be dispatched to locate facilities owned by that facility owner. This may be done by consulting a lookup table that maps facility types to skill requirements (e.g., the lookup table 2850 shown in FIG. 18).

At act 21604, the ticket assessment engine may determine whether the ticket is associated with any complexity types (e.g., as determined during the process 21200 shown in FIG. 22). If so, the ticket assessment engine may look up any skill requirements associated with the identified complexity types. For example, a complexity reason code “Military Base” may indicate that only technicians with certain levels of security clearance may gain access to the work site. As another example, a high profile ticket may require a high level of experience and/or good performance.

At act 21606, the ticket assessment engine may obtain a risk score for the ticket (e.g., as determined during the process 21400 shown in FIG. 24) and look up any applicable skill requirements. For example, a high risk ticket may require a technician with a high level of experience and/or good performance.

As with other types of assessment, some of the above-described functionalities relating to skill requirements assessment may be expressed via a set of business rules (e.g., one or more of business rules 2240 shown in FIG. 12). An exemplary skill requirements assessment business rule is described in Table 32 below.

13. Example of Work Order

FIG. 27 shows an example of a work order 21700 that may be created from an incoming locate request ticket (e.g., the ticket 300 shown in FIG. 3). As shown, the work order 21700 may include a plurality of information elements extracted from the ticket 2300, such as ticket number 21702, address of work site 21704, excavation information 21706, due date information 21708, excavator information 21710, etc. These information elements may be presented in the work order 21700 in a different format compared to the ticket 2300. The work order 21700 may also include additional information elements, such as a work order number 21712 different from the ticket number (e.g., multiple different work orders may be created based on the same ticket), an expected duration 21714 (e.g., as determined during the process 21130 shown in FIG. 23) and work order task information 21706 listing the facility types to be located within this work order.

The work order 21700 may be forwarded by the ticket assessment engine to other software applications for further processing. For example, the scheduling and dispatch application 2260 (as shown in FIG. 12) may schedule the work order to commence at a certain date and time (e.g., Jan. 4, 2009 at 9:00 AM, as shown in FIG. 27).

14. Backend and On-GOing Assessments

As discussed above, a feedback mechanism (e.g., the backend assessment module 2290 shown in FIG. 12) may be provided in accordance with some embodiments to review completed tickets and perform various information updates. For example, the various processes carried out by the ticket assessment engine 2230 may rely on historical information, such as statistical information regarding previously completed tickets. For improved performance and reliability, it may be desirable to update the historical and/or statistical information on an on-going basis, as more completed tickets are accumulated over time.

Additionally, the facility maps available from one-call centers and/or facility owners may not always contain sufficient and accurate information. For example, for some historic urban neighborhoods, the only available facility maps may have been created many years ago and may not contain absolute location information such as lat/long coordinates. Some of the street-level landmarks shown on the maps may have been moved or no longer exist. In such a situation, it may be difficult to determine the exact location of some of the facilities shown on the maps.

Thus, in accordance with some embodiments of the present disclosure, the GIS 2610 shown in FIG. 16 may be used as part of a system for continually improving the quality of available facility maps. For example, the GIS 2610 may be used to digitize existing maps printed on paper or cloth and augment the digitized maps with geospatial metadata.

In some instances, the geospatial metadata added to facility maps may be generated at least partially based on previously completed locate request tickets. For example, the backend assessment module 2290 shown in FIG. 12 may be adapted to recognize some geographic areas as areas with insufficient information and may forward to the GIS 2610 the results of completed location operations in those areas, which may include technician logs and/or geotagged images with technician annotations indicating marked facilities. Using this information, the GIS 2610 may be able to derive accurate location information for the marked facilities and augment the facility maps accordingly with some appropriate geospatial metadata.

As another example, the backend assessment module 2290 may be programmed to discover inconsistencies between existing facility maps and the actual result of a completed locate operation, and to notify the GIS 2610 of the discovered inconsistencies. Alternatively, the GIS 2610 may be adapted to receive from a human user an indication that there is an error on an existing facility map. In either situation, the GIS 2610 may be respond by verifying the report of inconsistency and correcting the facility map accordingly.

As yet another example, the backend assessment module 2290 may be programmed to make adjustments to the assessment business rules 2240 shown in FIG. 12. For example, any historical averages used in the assessment business rules 2240 may be updated on a regular basis. Also, new rules may be added as new patterns are observed from newly accumulated information. For example, a new rule may be defined that the estimated duration for all locate request tickets within 2 miles of central Manhattan, N.Y. may be adjusted upward by four minutes. Alternatively, a new complexity type may be created (e.g., “high density urban”) and new business rules may be defined accordingly.

### Table 8

<table>
<thead>
<tr>
<th>Number Category</th>
<th>Impacts</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BR-001 Complexity</td>
<td>Duration, Risk, Complexity</td>
<td>Keywords - Skill</td>
<td>Use keywords to predict complexity potential and/or high profile potential</td>
</tr>
</tbody>
</table>
### TABLE 8-continued

<table>
<thead>
<tr>
<th>Number</th>
<th>Category</th>
<th>Impacts</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BR-002</td>
<td>Complexity</td>
<td>Duration, Risk, Skill</td>
<td>Complexity Region - Complexity</td>
<td>Determine whether excavation notice is within a Complexity Region</td>
</tr>
<tr>
<td>BR-003</td>
<td>Complexity</td>
<td>Duration, Risk, Skill</td>
<td>Proximity to Historical High Profile - High Profile</td>
<td>Use proximity to historical high profile tickets to estimate high profile potential</td>
</tr>
<tr>
<td>BR-004</td>
<td>Complexity</td>
<td>Duration, Risk, Skill</td>
<td>Project/Hourly Scope - Complexity</td>
<td>Determine if a project/hourly scope applies to the excavation notice</td>
</tr>
<tr>
<td>BR-005</td>
<td>Complexity</td>
<td>Duration, Risk, Skill, Revenue</td>
<td>Emergency/Short Notice Type - Complexity</td>
<td>Determine if an emergency/short notice type applies to the excavation notice</td>
</tr>
<tr>
<td>BR-006</td>
<td>Duration</td>
<td>Duration</td>
<td>Locate Count - Duration</td>
<td>Use number of locates to set initial estimate of ticket duration</td>
</tr>
<tr>
<td>BR-007</td>
<td>Duration</td>
<td>Duration</td>
<td>Facility Type - Duration</td>
<td>Use facility types to be located to adjust estimated ticket duration</td>
</tr>
<tr>
<td>BR-008</td>
<td>Duration</td>
<td>Duration</td>
<td>High Profile - Duration</td>
<td>Use high profile certainty to adjust estimated ticket duration</td>
</tr>
<tr>
<td>BR-009</td>
<td>Duration</td>
<td>Duration</td>
<td>High Profile Potential - Duration</td>
<td>Use high profile potential to adjust estimated ticket duration</td>
</tr>
<tr>
<td>BR-010</td>
<td>Duration</td>
<td>Duration</td>
<td>Complexity Regions - Duration</td>
<td>Use complexity regions to adjust estimated ticket duration</td>
</tr>
<tr>
<td>BR-011</td>
<td>Duration</td>
<td>Duration</td>
<td>Service Type - Duration</td>
<td>Use the service type (emergency or short notice) to adjust estimated ticket duration</td>
</tr>
<tr>
<td>BR-012</td>
<td>Duration</td>
<td>Duration</td>
<td>Project/Hourly Scope - Duration</td>
<td>Adjust duration for project/hourly scope excavation notice</td>
</tr>
<tr>
<td>BR-013</td>
<td>Risk</td>
<td>Risk</td>
<td>Facility Types - Risk</td>
<td>Use facility types to estimate risk</td>
</tr>
<tr>
<td>BR-014</td>
<td>Risk</td>
<td>Risk</td>
<td>Proximity to Historical High Profile - Risk Excavator Damage History</td>
<td>Use proximity to historical damage reports to adjust estimated risk</td>
</tr>
<tr>
<td>BR-015</td>
<td>Risk</td>
<td>Risk</td>
<td>High Profile Potential - Risk</td>
<td>Use high profile potential to adjust estimated risk</td>
</tr>
<tr>
<td>BR-016</td>
<td>Risk</td>
<td>Risk</td>
<td>Service Type - Risk</td>
<td>Use the service type (emergency or short notice) to adjust estimated risk</td>
</tr>
<tr>
<td>BR-017</td>
<td>Risk</td>
<td>Risk</td>
<td>Project/Hourly Scope - Risk Excavation Notice ID</td>
<td>Adjust risk for project/hourly scope excavation notice</td>
</tr>
<tr>
<td>BR-018</td>
<td>Value</td>
<td>Value</td>
<td>Billing Rules Per Ticket - Value</td>
<td>Apply applicable Per Ticket billing business rates and rules to determine value</td>
</tr>
<tr>
<td>BR-019</td>
<td>Value</td>
<td>Value</td>
<td>Duplicate Ticket Rules - Value</td>
<td>Apply duplicate ticket rules to determine if billing value is zero</td>
</tr>
<tr>
<td>BR-020</td>
<td>Value</td>
<td>Value</td>
<td>Billing Rates By Unit- Value</td>
<td>Apply applicable By Unit billing business rates and rules to determine value</td>
</tr>
<tr>
<td>BR-021</td>
<td>Value</td>
<td>Value</td>
<td>Project/Hourly Scope - Value Excavation Notice ID, Work Order Number, Task ID, locate instruction text, comment text, excavation type description</td>
<td>Adjust value for project/hourly scope excavation notice</td>
</tr>
<tr>
<td>BR-022</td>
<td>Skill</td>
<td>Skill</td>
<td>Determine Skill Requirements - Skill</td>
<td>Determine skill requirements for the excavation notice</td>
</tr>
</tbody>
</table>

### TABLE 9

**First example complexity determination of assessment business rules 2240**

<table>
<thead>
<tr>
<th>Business Rule ID</th>
<th>Keywords - Complexity</th>
<th>BR Category: CPL</th>
<th>Example</th>
<th>Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>BR-001 (of Table 8)</td>
<td>Use keywords to predict complexity potential and/or high profile potential</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IF excavation type description contains FiOS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>THEN complexity type = High Profile Potential</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| The keywords will be stored in a decision table as an input column, with corresponding values for complexity type and high potential reason description. For example:
**TABLE 9-continued**

<table>
<thead>
<tr>
<th>KEYWORD-</th>
<th>HIGH PROFILE</th>
<th>REASON</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMPLEXITY</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TYPE</td>
<td>FiOS</td>
<td></td>
<td>Military Base</td>
</tr>
<tr>
<td></td>
<td>Gated</td>
<td></td>
<td>Aerial Power Lines</td>
</tr>
</tbody>
</table>

**TABLE 10**

<table>
<thead>
<tr>
<th>Business Rule</th>
<th>Complexity Region - Complexity</th>
<th>BR Category: CPL</th>
</tr>
</thead>
<tbody>
<tr>
<td>BR-002</td>
<td>Determine whether excavation notice is within a complexity region.</td>
<td></td>
</tr>
</tbody>
</table>

**TABLE 11**

<table>
<thead>
<tr>
<th>Business Rule</th>
<th>Proximity to Historical High Profile - High Profile</th>
</tr>
</thead>
<tbody>
<tr>
<td>BR-003</td>
<td>Use proximity to historical high profile tickets to estimate high profile potential.</td>
</tr>
</tbody>
</table>

**TABLE 12**

<table>
<thead>
<tr>
<th>Business Rule</th>
<th>Project/Hours Scope - Complexity</th>
<th>BR Category: CPL</th>
</tr>
</thead>
<tbody>
<tr>
<td>BR-004</td>
<td>Determine if a project/hours scope applies to the excavation notice.</td>
<td></td>
</tr>
</tbody>
</table>

**TABLE 12-continued**

<table>
<thead>
<tr>
<th>Rule Operation</th>
<th>IF size of locate area in miles is greater than 0.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example</td>
<td>THEN Hourly Status Indicator = True</td>
</tr>
<tr>
<td>Implementation</td>
<td>The decision factors leading to hourly status designation center upon the complexity and size of the locate task, and travel considerations such as whether the work site is a remote/rural area or desert location. Decisions will be based upon dimensional fields (Size of Locate Area, Footage, Miles, Bounded By) and keyword fields (locate instruction text, comment text, excavation type description). Business rules such as this one, which are derived based upon billing tables, will need to undergo definition and validation prior to rollout in any given location. This is due to the fact that the rules can differ from contract-to-contract, and by area to area within a state.</td>
</tr>
</tbody>
</table>

**TABLE 13**

<table>
<thead>
<tr>
<th>Business Rule</th>
<th>Emergency/Short Notice - Complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td>BR-005</td>
<td>Determine if an emergency/short notice type applies to the excavation notice.</td>
</tr>
</tbody>
</table>

**TABLE 14**

<table>
<thead>
<tr>
<th>Business Rule</th>
<th>Locate Count - Duration</th>
<th>BR Category: DUR</th>
</tr>
</thead>
<tbody>
<tr>
<td>BR-006</td>
<td>Use number of locates to set an initial estimate of ticket duration.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LOCATE COUNT</th>
<th>AVG DURATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>3</td>
<td>19</td>
</tr>
</tbody>
</table>
### TABLE 15

Second example duration estimation of assessment business rules 2240

<table>
<thead>
<tr>
<th>Business Rule ID</th>
<th>Business Rule Name</th>
<th>Business Rule Description</th>
<th>Fields Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>BR-007 (of Table 8)</td>
<td>Facility Type - Duration</td>
<td>Use facility types to be located to adjust estimated ticket duration</td>
<td>util_type_code, disp_type_code, util_locate_request.util_type_code, util_locate_request.util_locate_request_id, work_order_locate_task.util_locate_request_id, work_order_locate_task.work_order_id</td>
</tr>
</tbody>
</table>

### TABLE 15-continued

Second example duration estimation of assessment business rules 2240

<table>
<thead>
<tr>
<th>Rule Operation</th>
<th>Example</th>
<th>Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>IF Facility Type Codes include Gas</td>
<td>THEN duration = duration * 4</td>
<td>The facility type values with associated adjustment values are stored in locate_assess_code. Note that the reason that, for example, the sewer number might be a negative offset, is that statistics might tell us that 3-locate tickets with sewer are, on average, 3 minutes shorter in duration than 3-locate tickets without a sewer locate. For example:</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FACILITY TYPE</th>
<th>DURATION OFFSET</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas</td>
<td>4</td>
</tr>
<tr>
<td>Sewer</td>
<td>-3</td>
</tr>
<tr>
<td>Water</td>
<td>-2</td>
</tr>
</tbody>
</table>

### TABLE 16

Third example duration estimation of assessment business rules 2240

<table>
<thead>
<tr>
<th>Business Rule ID</th>
<th>Business Rule Name</th>
<th>Business Rule Description</th>
<th>Fields Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>BR-008 (of Table 8)</td>
<td>High Profile - Duration</td>
<td>Use high profile certainty to adjust estimated ticket duration</td>
<td>high_profile_reason_code, disp_profile_reason_code, util_locate_high_profile_reason.util_locate_request_id, util_locate_request.util_locate_request_id, work_order_locate_task.util_locate_request_id, work_order_locate_task.work_order_id</td>
</tr>
</tbody>
</table>

### TABLE 16-continued

<table>
<thead>
<tr>
<th>Rule Operation</th>
<th>Example</th>
<th>Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>IF High Profile Reason Code = HCPFONE</td>
<td>THEN duration = duration * 1.23</td>
<td>The high profile reason codes will be stored in a decision table as an input column, with corresponding multiplier values for ticket duration. For example:</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>HIGH PROFILE REASON CODE</th>
<th>HP REASON DESCRIPTION</th>
<th>DURATION MULTIPLIER</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>no reason</td>
<td>1.15</td>
</tr>
<tr>
<td>FiOS</td>
<td>Fiber Optic</td>
<td>1.38</td>
</tr>
<tr>
<td>HCPFONE</td>
<td>High Capacity Phone Line</td>
<td>1.23</td>
</tr>
</tbody>
</table>

### TABLE 17

Fourth example duration estimation of assessment business rules 2240

<table>
<thead>
<tr>
<th>Business Rule ID</th>
<th>Business Rule Name</th>
<th>Business Rule Description</th>
<th>Fields Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>BR-009 (of Table 8)</td>
<td>High Profile Potential - Duration</td>
<td>Use proximity to historical high profile areas to adjust estimated ticket duration</td>
<td>work_order_locate_abr, work_order_loc_abbr, high_profile_service_area.high_profile_reason_code, high_profile_reason_code, util_locate_request.util_locate_request_id, util_locate_request.util_locate_request_id, work_order_locate_task.work_order_id, work_order_locate_task.util_locate_request_id</td>
</tr>
</tbody>
</table>

### TABLE 17-continued

<table>
<thead>
<tr>
<th>Rule Operation</th>
<th>Example</th>
<th>Implementation</th>
</tr>
</thead>
</table>
| IF High Profile Potential Reason Code = HCPFONE | THEN duration = duration * 1.18 | The high profile reason codes will be stored in a decision table as an input column, with corresponding multiplier values for ticket duration. For example:
### TABLE 17-continued

<table>
<thead>
<tr>
<th>HI PROFILE REASON CODE</th>
<th>HP POTENTIAL REASON DESCRIPTION</th>
<th>DURATION MULTIPLIER</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>no reason</td>
<td>1.08</td>
</tr>
<tr>
<td>FIOS</td>
<td>Fiber Optic</td>
<td>1.30</td>
</tr>
<tr>
<td>HC PHONE</td>
<td>High Capacity Phone Line</td>
<td>1.18</td>
</tr>
</tbody>
</table>

### TABLE 18

Fifth example duration estimation of assessment business rules 2240

<table>
<thead>
<tr>
<th>Business Rule ID</th>
<th>Business Rule Name</th>
<th>Complexity Regions - Duration</th>
<th>BR Category:</th>
</tr>
</thead>
<tbody>
<tr>
<td>BR-010 (of Table 8)</td>
<td></td>
<td></td>
<td>DUR</td>
</tr>
</tbody>
</table>

**Business Rule Description:** Use complexity regions to adjust estimated ticket duration. Determine if work order is in a complexity region by determining whether the work order location is inside a defined complexity area.

**Fields Required:**
- complexity_reason_code
- complexity_service_area.service_area_id
- service_area_coordinates.seq_nbr
- service_area_coordinates.lat_nbr
- service_area_coordinates.long_nbr
- service_area_coordinates.spatial_type_code
- service_area.service_area_id
- work_order.lat_nbr
- work_order.long_nbr

**Rule Operation Example:** IF Complexity Region Type = Military Base THEN duration = duration + 35

**Implementation:** The complexity region type codes will be stored in a decision table as an input column, with corresponding multiplier values for ticket duration. For example:

<table>
<thead>
<tr>
<th>COMPLEXITY REGION TYPE</th>
<th>DURATION OFFSET</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gated</td>
<td>15</td>
</tr>
<tr>
<td>Military Base</td>
<td>35</td>
</tr>
<tr>
<td>Aerial</td>
<td>-10</td>
</tr>
</tbody>
</table>

### TABLE 19

Sixth example duration estimation of assessment business rules 2240

<table>
<thead>
<tr>
<th>Business Rule ID</th>
<th>Business Rule Name</th>
<th>Service Type - Duration</th>
<th>BR Category:</th>
</tr>
</thead>
<tbody>
<tr>
<td>BR-011 (of Table 8)</td>
<td></td>
<td></td>
<td>DUR</td>
</tr>
</tbody>
</table>

**Business Rule Description:** Use the service type (emergency or short notice) to adjust estimated ticket duration

**Fields Required:**
- work_order.locate_task
- work_order_id
- excavata_notice.ticket_type_code
- client.locate_request.excavata_notice_id
- excavata.notice.excavata_notice_id
- util.locate_request.util_locate_request_id
- ticket_type_code.displ_type_code

**Rule Operation Example:** IF Service Type = Emergency THEN duration = duration * 1.43

**Implementation:** The service types will be stored in a decision table as an input column, with corresponding multiplier values for ticket duration. For example:

<table>
<thead>
<tr>
<th>SERVICE TYPE</th>
<th>DURATION MULTIPLIER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergency</td>
<td>1.23</td>
</tr>
<tr>
<td>Short Notice</td>
<td>1.82</td>
</tr>
</tbody>
</table>

### TABLE 20

Seventh example duration estimation of assessment business rules 2240

<table>
<thead>
<tr>
<th>Business Rule ID</th>
<th>Business Rule Name</th>
<th>Project/Hourly Scope - Duration</th>
<th>BR Category:</th>
</tr>
</thead>
<tbody>
<tr>
<td>BR-012 (of Table 8)</td>
<td></td>
<td></td>
<td>DUR</td>
</tr>
</tbody>
</table>

**Business Rule Description:** Adjust duration for project/hourly scope excavation notice

**Fields Required:**
- excavata.notice.site_dig_length
- excavata_notice.site_dig_width
- excavata.notice.site_dig_depth
- excavata.notice.site_dig_length uom code
- excavata_notice.site_dig_width uom code
- excavata_notice.site_dig_depth uom code
- excavata_notice.excavata_notice_id
**TABLE 20-continued**

Seventh example duration estimation of assessment business rules 2240

<table>
<thead>
<tr>
<th>Rule Operation</th>
<th>Example Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>IF excavation size greater than minimum for project scope status</td>
<td>THEN duration = duration * (size of locate area in miles) / 0.5</td>
</tr>
<tr>
<td>1. If the dig dimension fields are not populated, ignore this rule.</td>
<td></td>
</tr>
<tr>
<td>2. If the dig dimension fields are populated, and if the dig square footage is over the stored lookup value for square feet (e.g., 10,000), adjust the duration upwards in proportion to the ratio for square footage.</td>
<td></td>
</tr>
<tr>
<td>3. If the dig dimension fields are populated, and item 2 does not apply, and if the dig length is above the stored lookup value for length in miles, adjust the duration upwards in proportion to the ratio for linear miles.</td>
<td></td>
</tr>
</tbody>
</table>

For example:

<table>
<thead>
<tr>
<th>SCOPE MEASURABLE BASELINE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of Locate Area</td>
</tr>
<tr>
<td>Footage</td>
</tr>
</tbody>
</table>

| TABLE 21  |

First example risk estimation of assessment business rules 2240

- **Business Rule ID**: BR-013 (of Table 8)
- **Business Rule Name**: Facility Types - Risk
- **BR Category**: RSK
- **Business Rule Description**: Use facility types to estimate risk
- **Fields Required**: Excavation Notice ID, Work Order Number, Task ID, Facility Type

<table>
<thead>
<tr>
<th>FACILITY TYPE DESCRIPTION</th>
<th>FACILITY TYPE RISK VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas</td>
<td>2.5</td>
</tr>
<tr>
<td>Electric</td>
<td>0.7</td>
</tr>
<tr>
<td>Water</td>
<td>0.2</td>
</tr>
</tbody>
</table>

**TABLE 21-continued**

First example risk estimation of assessment business rules 2240

- **Example Rule Operation**: IF facility type descriptions contain gas and water THEN Risk = 2.5 + 0.2 = 2.7
- **Example Implementation**: The facility types will be stored in a decision table as an input column, with corresponding values for additive facility type risk values. For example:

<table>
<thead>
<tr>
<th>FACILITY TYPE DESCRIPTION</th>
<th>FACILITY TYPE RISK VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas</td>
<td>2.5</td>
</tr>
<tr>
<td>Electric</td>
<td>0.7</td>
</tr>
<tr>
<td>Water</td>
<td>0.2</td>
</tr>
</tbody>
</table>

**TABLE 22**

Second example risk estimation of assessment business rules 2240

- **Business Rule ID**: BR-014 (of Table 8)
- **Business Rule Name**: Proximity to Historical High Profile - Risk
- **BR Category**: RSK
- **Business Rule Description**: Use proximity to historical damage reports to adjust estimated risk
- **Fields Required**: Excavation Notice ID, Work Order Number, Task ID, lat number, long number, damage latitude, damage longitude, damage amount
- **Example Rule Operation**: IF work location is within a 500 yard radius of one or more damage report historical locations totaling $15,000 THEN Risk = Risk * 2.0
- **Example Implementation**: The $15,000 figure cited above is only an example, the actual criteria will be defined by Risk Management based upon historical statistics, and will be specific to an individual area. Historical damage reports will be retained along with excavator, damage cost, facility type, and latitude/longitude coordinates which define the damage location. For example:

<table>
<thead>
<tr>
<th>MIN DAMAGE</th>
<th>MAX DAMAGE</th>
<th>RISK MULTIPLIER</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10000</td>
<td>1.1</td>
</tr>
<tr>
<td>1000</td>
<td>10000</td>
<td>1.3</td>
</tr>
<tr>
<td>10000</td>
<td>100000</td>
<td>2.0</td>
</tr>
<tr>
<td>100000</td>
<td>1000000</td>
<td>4.0</td>
</tr>
</tbody>
</table>
### TABLE 23
Third example risk estimation of assessment business rules 2240

<table>
<thead>
<tr>
<th>Business Rule</th>
<th>BR-015 (of Table 8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID</td>
<td></td>
</tr>
<tr>
<td>Business Rule Name</td>
<td>Excavator Damage History - Risk</td>
</tr>
<tr>
<td>Business Rule Description</td>
<td>Use excavator damage history to adjust estimated risk</td>
</tr>
<tr>
<td>Fields Required</td>
<td>Excavation Notice ID, Work Order Number, Task ID, lat member, long member, excavator, excavator damage amount, excavator damage count, excavator locate count</td>
</tr>
<tr>
<td>Rule Operation Example</td>
<td>IF High Profile Potential Reason Code Is Between 100 and 300</td>
</tr>
<tr>
<td>Implementation</td>
<td>THEN risk = risk * 2.0</td>
</tr>
</tbody>
</table>

Additionaly, risk multipliers will be applied for excavator damage count:

<table>
<thead>
<tr>
<th>DAMAGE AMOUNT PER LOCATE AS</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAXIMUM EXCAVATOR</td>
</tr>
<tr>
<td>PERCENTAGE</td>
</tr>
<tr>
<td>RISK MULTIPLIER</td>
</tr>
</tbody>
</table>

### TABLE 24
Fourth example risk estimation of assessment business rules 2240

<table>
<thead>
<tr>
<th>Business Rule ID</th>
<th>BR-016 (of Table 8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business Rule Name</td>
<td>High Profile Potential - Risk</td>
</tr>
<tr>
<td>Business Rule Description</td>
<td>Use high profile potential to adjust estimated risk</td>
</tr>
<tr>
<td>Fields Required</td>
<td>Excavation Notice ID, Work Order Number, Task ID, High Profile Potential (derived), High Profile Potential Reason (derived)</td>
</tr>
<tr>
<td>Rule Operation Example</td>
<td>IF High Profile Potential Reason Description = Fiber Optic</td>
</tr>
<tr>
<td>Implementation</td>
<td>THEN risk = risk * 4.0</td>
</tr>
</tbody>
</table>

The high profile reason codes will be stored in a decision table as an input column, with corresponding multiplier values for risk. For example:

<table>
<thead>
<tr>
<th>HP POTENTIAL REASON</th>
<th>HP POTENTIAL DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>581</td>
<td>no reason 1.8</td>
</tr>
<tr>
<td>585</td>
<td>Fiber Optic 4.0</td>
</tr>
<tr>
<td>586</td>
<td>High Capacity Phone Line 2.5</td>
</tr>
</tbody>
</table>

### TABLE 25
Fifth example risk estimation of assessment business rules 2240

<table>
<thead>
<tr>
<th>Business Rule ID</th>
<th>BR-017 (of Table 8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business Rule Name</td>
<td>Service Type - Risk</td>
</tr>
<tr>
<td>Business Rule Description</td>
<td>Use the service type (emergency or short notice)</td>
</tr>
<tr>
<td>Fields Required</td>
<td>Excavation Notice ID, Work Order Number, Task ID, Service Type</td>
</tr>
<tr>
<td>Rule Operation Example</td>
<td>IF Service Type = Emergency</td>
</tr>
<tr>
<td>Implementation</td>
<td>THEN risk = risk * 2.85</td>
</tr>
</tbody>
</table>

The service types will be stored in a decision table as an input column, with corresponding multiplier values for ticket duration. For example:

<table>
<thead>
<tr>
<th>SERVICE TYPE</th>
<th>RISK MULTIPLIER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergency</td>
<td>2.85</td>
</tr>
<tr>
<td>Short Notice - 2 hours</td>
<td>3.46</td>
</tr>
<tr>
<td>Short Notice - 3 hours</td>
<td>3.11</td>
</tr>
</tbody>
</table>

### TABLE 26
Sixth example risk estimation of assessment business rules 2240

<table>
<thead>
<tr>
<th>Business Rule ID</th>
<th>BR-018 (of Table 8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business Rule Name</td>
<td>Project/ Hourly Scope - Risk</td>
</tr>
<tr>
<td>Business Rule Description</td>
<td>Adjust risk for project/hourly scope excavation notice</td>
</tr>
<tr>
<td>Fields Required</td>
<td>Excavation Notice ID, Work Order Number, Task ID, Hourly Status Indicator, Size of Locate Area, Footage, Miles, Bounded By</td>
</tr>
<tr>
<td>Rule Operation Example</td>
<td>IF Hourly Status Indicator = True</td>
</tr>
<tr>
<td>Implementation</td>
<td>The risk adjustment will be proportional to the appropriate locate size field, divided by the baseline appropriate to that field. For example:</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SCOPE MEASURABLE</th>
<th>BASELINE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size of Locate Area</td>
<td>0.5 miles</td>
</tr>
<tr>
<td>Footage</td>
<td>10000 sq ft</td>
</tr>
</tbody>
</table>

### TABLE 27
First example value estimation of assessment business rules 2240

<table>
<thead>
<tr>
<th>Business Rule ID</th>
<th>BR-019 (of Table 8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business Rule Name</td>
<td>Billing Rules Per Ticket - Value</td>
</tr>
<tr>
<td>Business Rule Description</td>
<td>Use estimated located value to estimate ticket value</td>
</tr>
<tr>
<td>Fields Required</td>
<td>Excavation Notice ID, Work Order Number, Task ID, Member Code, Estimated Located Value (Derived from Billing Rate Tables)</td>
</tr>
<tr>
<td>Rule Operation Example</td>
<td>IF Estimated Located Value equals $35.50</td>
</tr>
<tr>
<td>Implementation</td>
<td>THEN Value = $35.50</td>
</tr>
</tbody>
</table>

If the billing method associated with the client is "Per Ticket" or "Per Transaction", then assume a located, normal, closed ticket. Then lookup the billing rate value associated with the member code associated with the facility locate request and a located, normal, closed ticket.
### TABLE 28

Second example value estimation of assessment business rules 2240

<table>
<thead>
<tr>
<th>Business Rule ID</th>
<th>Business Rule Name</th>
<th>Business Rule Description</th>
<th>Fields Required</th>
<th>Rule Operation</th>
<th>Example</th>
<th>Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>BR-020 (of Table 8)</td>
<td>Duplicate Ticket Rules - Value</td>
<td>BR Category: VAL</td>
<td>Ticket ID, Work Order ID, Task ID</td>
<td>IF Ticket = &quot;Dup&quot; THEN Value = 0</td>
<td>THEN Value = 0</td>
<td>A subset of the billing subsystem business rules deal with the application of duplicate ticket rules applicable to many service contracts. Many client contracts stipulate that the locating company cannot charge for services performed on a duplicate ticket. There contracts also stipulate what conditions define a duplicate ticket. For example, a contract may define a duplicate ticket as two or more tickets transmitted on the same business day with identical excavation sites.</td>
</tr>
</tbody>
</table>

### TABLE 29-continued

<table>
<thead>
<tr>
<th>Business Rule ID</th>
<th>Business Rule Name</th>
<th>Business Rule Description</th>
<th>Fields Required</th>
<th>Rule Operation</th>
<th>Example</th>
<th>Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>BR-AE-021</td>
<td>Billing Rates By Unit - Value</td>
<td>BR Category: VAL</td>
<td>Ticket Number, Ticket Type, Contract-specific attributes</td>
<td>IF member code equals 74538 and quantity equals 1 THEN Value = 25.75</td>
<td>IF member code equals 74538 and quantity equals 1 THEN Value = 25.75</td>
<td>If the billing method associated with the client is &quot;By Unit&quot;, then assume a quantity of 1 (this would mean that the lowest linear foot in the billing table would be applied). Then lookup the billing rate value associated with the member code associated with the utility locate request and a quantity of one.</td>
</tr>
</tbody>
</table>
While various inventive embodiments have been described and illustrated herein, those of ordinary skill in the art will readily envision a variety of other means and/or structures for performing the function and/or obtaining the results and/or one or more of the advantages described herein, and each of such variations and/or modifications is deemed to be within the scope of the inventive embodiments described herein. More generally, those skilled in the art will readily appreciate that all parameters, dimensions, materials, and configurations described herein are meant to be exemplary and that the actual parameters, dimensions, materials, and/or configurations will depend upon the specific application or applications for which the inventive teachings are used. Those skilled in the art will recognize, or be able to ascertain using no more than routine experimentation, many equivalents to the specific inventive embodiments described herein. It is, therefore, to be understood that the foregoing embodiments are presented by way of example only and that, within the scope of the appended claims and equivalents thereto, inventive embodiments may be practiced otherwise than as specifically described and claimed. Inventive embodiments of the present disclosure are directed to each individual feature, system, article, material, kit, and/or method described herein. In addition, any combination of two or more such features, systems, articles, materials, kits, and/or methods, if such features, systems, articles, materials, kits, and/or methods are not mutually inconsistent, is included within the inventive scope of the present disclosure.

The above-described embodiments may be implemented in any of numerous ways. For example, the embodiments may be implemented using hardware, software or a combination thereof. When implemented in software, the software code can be executed on any suitable processor or collection of processors, whether provided in a single computer or distributed among multiple computers.

FIG. 28 shows an illustrative computer 21800 that may be used for improving information management, dissemination, and utilization in the locate industry and other field service industries, in accordance with some embodiments. For example, the computer 21800 comprises a memory 21810, one or more processing units 21812, one or more communication interfaces 21814, one or more display units 21816, and one or more user input devices 21818. The memory 21810 may comprise any computer-readable medium, and may store computer instructions for implementing various components of a ticket management system, such as the ticket parser 2210 and the ticket assessment engine 2230 shown in FIG. 12 and the geographic information system 2610 shown in FIG. 16. The processing unit(s) 21812 may be used to execute the instructions implementing these software components. The communication interface(s) 21814 may be coupled to a wired or wireless network, bus, or other communication means and may therefore allow the computer 21800 to transmit communications to and/or receive communications from other devices. The display unit(s) 21816 may be provided, for example, to allow a human user to view assessment outcomes produced by the ticket assessment engine 2230. The user input device(s) 21818 may be provided, for example, to allow the human user to make any desired manual adjustments to the assessment outcomes.

The various methods or processes outlined herein may be coded as software that is executable on one or more processors that employ any one of a variety of operating systems or platforms. Additionally, such software may be written using any of a number of suitable programming languages and/or programming or scripting tools, and also may be compiled as executable machine language code or intermediate code that is executed on a framework or virtual machine.

In this respect, various inventive concepts may be embodied as a computer readable storage medium (or multiple computer readable storage media) (e.g., a computer memory, one or more floppy discs, compact discs, optical discs, magnetic tapes, flash memories, circuit configurations in Field Programmable Gate Arrays or other semiconductor devices, or other tangible computer storage medium) encoded with one or more programs that, when executed on one or more computers or other processors, perform methods that implement the various embodiments of the inven-

---

### TABLE 30

<table>
<thead>
<tr>
<th>Rule Operation</th>
<th>Example</th>
<th>Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value for project/hourly scope excavation notice</td>
<td>THEN value = 4 * (size of locate area in miles)/0.5</td>
<td>Value for hourly projects is governed by the billing tables (per contractual terms). Most contracts pay on unit pay rather than hourly. If the contract allows for per hour billing, then the value adjustment will be proportional to the appropriate locate size field, multiplied by the baseline hours for that field, divided by the baseline appropriate to that field. For example:</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SCOPE BASELINE SIZE HOURS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size of Locate Area</td>
</tr>
<tr>
<td>Footage</td>
</tr>
</tbody>
</table>

### TABLE 31

<table>
<thead>
<tr>
<th>Rule Operation</th>
<th>Example</th>
<th>Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value for project/hourly scope excavation notice</td>
<td>THEN value = 4 * (size of locate area in miles)/0.5</td>
<td>Value for hourly projects is governed by the billing tables (per contractual terms). Most contracts pay on unit pay rather than hourly. If the contract allows for per hour billing, then the value adjustment will be proportional to the appropriate locate size field, multiplied by the baseline hours for that field, divided by the baseline appropriate to that field. For example:</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SCOPE BASELINE SIZE HOURS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size of Locate Area</td>
</tr>
<tr>
<td>Footage</td>
</tr>
</tbody>
</table>

### TABLE 32

<table>
<thead>
<tr>
<th>Rule Operation</th>
<th>Example</th>
<th>Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value for project/hourly scope excavation notice</td>
<td>THEN value = 4 * (size of locate area in miles)/0.5</td>
<td>Value for hourly projects is governed by the billing tables (per contractual terms). Most contracts pay on unit pay rather than hourly. If the contract allows for per hour billing, then the value adjustment will be proportional to the appropriate locate size field, multiplied by the baseline hours for that field, divided by the baseline appropriate to that field. For example:</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SCOPE BASELINE SIZE HOURS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size of Locate Area</td>
</tr>
<tr>
<td>Footage</td>
</tr>
</tbody>
</table>

### TABLE 33

<table>
<thead>
<tr>
<th>Rule Operation</th>
<th>Example</th>
<th>Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value for project/hourly scope excavation notice</td>
<td>THEN value = 4 * (size of locate area in miles)/0.5</td>
<td>Value for hourly projects is governed by the billing tables (per contractual terms). Most contracts pay on unit pay rather than hourly. If the contract allows for per hour billing, then the value adjustment will be proportional to the appropriate locate size field, multiplied by the baseline hours for that field, divided by the baseline appropriate to that field. For example:</td>
</tr>
</tbody>
</table>
tion discussed above. The computer readable medium or media can be transportable, such that the program or programs stored thereon can be loaded onto one or more different computers or other processors to implement various aspects of the present invention as discussed above.

The terms “program” or “software” are used herein in a generic sense to refer to any type of computer code or set of computer-executable instructions that can be employed to program a computer or other processor to implement various aspects of embodiments as discussed above. Additionally, it should be appreciated that according to one aspect, one or more computer programs that when executed perform methods of the present invention need not reside on a single computer or processor, but may be distributed in a modular fashion amongst a number of different computers or processors to implement various aspects of the present invention.

Computer-executable instructions may be in many forms, such as program modules, executed by one or more computers or other devices. Generally, program modules include routines, programs, objects, components, data structures, etc. that perform particular tasks or implement particular abstract data types. Typically the functionality of the program modules may be combined or distributed as desired in various embodiments.

Also, data structures may be stored in computer-readable media in any suitable form. For simplicity of illustration, data structures may be shown to have fields that are related through location in the data structure. Such relationships may likewise be achieved by assigning storage for the fields with locations in a computer-readable medium that convey relationship between the fields. However, any suitable mechanism may be used to establish a relationship between information in fields of a data structure, including through the use of pointers, tags or other mechanisms that establish relationship between data elements.

Also, various inventive concepts may be embodied as one or more methods, of which an example has been provided. The acts performed as part of the method may be ordered in any suitable way. Accordingly, embodiments may be constructed in which acts are performed in an order different than illustrated, which may include performing some acts simultaneously, even though shown as sequential acts in illustrative embodiments.

All definitions, as defined and used herein, should be understood to control over dictionary definitions, definitions in documents incorporated by reference, and/or ordinary meanings of the defined terms.

The indefinite articles “a” and “an,” as used herein in the specification and in the claims, unless clearly indicated to the contrary, should be understood to mean “at least one.”

The phrase “and/or,” as used herein in the specification and in the claims, should be understood to mean “either or both” of the elements so conjointed, i.e., elements that are conjunctively present in some cases and disjunctively present in other cases. Multiple elements listed with “and/or” should be construed in the same fashion, i.e., “one or more” of the elements so conjointed. Other elements may optionally be present other than the elements specifically identified by the “and/or” clause, whether related or unrelated to those elements specifically identified. Thus, as a non-limiting example, a reference to “A and/or B,” when used in conjunction with open-ended language such as “comprising,” can refer, in one embodiment, to A only (optionally including elements other than B); in another embodiment, to B only (optionally including elements other than A); in yet another embodiment, to both A and B (optionally including other elements); etc.

As used herein in the specification and in the claims, “or” should be understood to have the same meaning as “and/or” as defined above. For example, when separating items in a list, “or” or “and/or” shall be interpreted as being inclusive, i.e., the inclusion of at least one, but also including more than one, of a number or list of elements, and, optionally, additional unlisted items. Only terms clearly indicated to the contrary, such as “only one of” or “exactly one of,” or, when used in the claims, “consisting of,” will refer to the inclusion of exactly one element of a number or list of elements. In general, the term “or” as used herein shall only be interpreted as indicating exclusive alternatives (i.e. “one or the other but not both”) when preceded by terms of exclusivity, such as “either,” “one of,” “only one of,” or “exactly one of.” “Consisting essentially of,” when used in the claims, shall have its ordinary meaning as used in the field of patent law.

As used herein in the specification and in the claims, the phrase “at least one,” in reference to a list of one or more elements, should be understood to mean at least one element selected from any one or more of the elements in the list of elements, but not necessarily including at least one of each and every element specifically listed within the list of elements and not excluding any combinations of elements in the list of elements. This definition also allows that elements may optionally be present other than the elements specifically identified within the list of elements to which the phrase “at least one” refers, whether related or unrelated to those elements specifically identified. Thus, as a non-limiting example, “at least one of A and B” (or, equivalently, “at least one of A or B,” or, equivalently “at least one of A and/or B”) can refer, in one embodiment, to at least one, optionally including more than one, A, with no B present (and optionally including elements other than B); in another embodiment, to at least one, optionally including more than one, B, with no A present (and optionally including elements other than A); in yet another embodiment, to at least one, optionally including more than one, A, and at least one, optionally including more than one, B (and optionally including other elements); etc.

In the claims, as well as in the specification above, all transitional phrases such as “comprising,” “including,” “carrying,” “having,” “containing,” “involving,” “holding,” “composed of,” and the like are to be understood to be open-ended, i.e., to mean including but not limited to. Only the transitional phrases “consisting of,” and “consisting essentially of” shall be closed or semi-closed transitional phrases, respectively, as set forth in the United States Patent Office Manual of Patent Examining Procedures, Section 2111.03.

What is claimed is:

1. An apparatus for providing a resource to complete a locate and/or marking operation, the apparatus comprising: at least one communication interface; at least one memory to store processor-executable instructions; and at least one processor communicatively coupled to the at least one memory and the at least one communication interface, wherein upon execution of the processor-executable instructions by the at least one processor, the at least one processor:

A) controls the at least one communication interface so as to receive a locate request ticket generated by a one-call center to specify the locate and/or marking operation, the locate and/or marking operation comprising detect-
ing and/or marking a presence or an absence of at least one underground facility within a dig area at a work site, wherein at least a portion of the dig area is planned to be excavated or disturbed during excavation activities at the work site;

B) parses the locate request ticket received in A) so as to extract ticket information obtained from the locate request ticket;

C) generates an Extensible Markup Language (XML) format file comprising the extracted ticket information;

D) performs a statistical analysis of historical information, the historical information being selected based at least in part on the XML format file generated in C) and including at least one of:

- historical damage reports for underground facility infrastructure;
- historical records of previously completed locate request tickets;

E) automatically assigns at least one risk designation to the locate request ticket based at least in part on the statistical analysis of the historical information performed in D); and

F) controls the at least one communication interface to transmit, and/or controls the at least one memory to store, the at least one risk designation so as to facilitate clearing the locate request ticket and/or dispatching at least one locate technician to perform the locate and/or marking operation, based at least in part on the at least one risk designation automatically assigned in E).

2. The apparatus of claim 1, wherein the at least one risk designation comprises a numerical score.

3. The apparatus of claim 1, wherein the at least one processor further:

G) determines at least one dispatch schedule for the locate and/or marking operation based at least in part on the at least one risk designation.

4. The apparatus of claim 1, wherein the at least one processor further:

G) determines at least one billing rule for billing the locate and/or marking operation to a customer based at least in part on the at least one risk designation.

5. The apparatus of claim 1, wherein the at least one processor further:

G) determines at least one resource requirement based at least in part on the at least one risk designation, wherein the at least one resource requirement comprises at least one of:

- a technician skill requirement of the at least one locate technician to be dispatched; and
- an equipment requirement for at least one piece of equipment to be used by the dispatched at least one locate technician during the locate and/or marking operation.

6. The apparatus of claim 1, wherein:

the XML format file generated in C) includes type information relating to at least one type of underground facility specified in the locate request ticket; and

in D), the historical information is selected for statistical analysis based at least in part on the type information relating to the at least one type of underground facility specified in the locate request ticket.

7. The apparatus of claim 6, wherein:

the historical information includes the historical damage reports;

in D), the at least one processor performs the statistical analysis of the historical damage reports to determine a frequency of damages relating to the at least one type of underground facility and/or a damage cost associated with the at least one type of underground facility; and in E), the at least one processor automatically assigns the at least one risk designation to the locate request ticket based at least in part on the frequency of damages relating to the at least one type of underground facility and/or the damage cost associated with the at least one type of underground facility.

8. The apparatus of claim 1, wherein:

the XML format file generated in C) includes excavator information relating to at least one excavator specified in the locate request ticket; and

in D), the historical information is selected for statistical analysis based at least in part on the excavator information relating to the at least one excavator specified in the locate request ticket.

9. The apparatus of claim 8, wherein:

the historical information includes the historical damage reports; and

the historical damage reports include an excavator damage history for the at least one excavator specified in the locate request ticket.

10. The apparatus of claim 9, wherein:

the excavator damage history includes excavator damage costs and/or excavator damage counts; and

in E), the at least one processor automatically assigns the at least one risk designation to the locate request ticket based at least in part on the excavator damage costs and/or excavator damage counts.

11. The apparatus of claim 8, wherein:

the historical information includes at least some of the historical reports of previously completed locate request tickets that indicate the at least one excavator.

12. The apparatus of any one of claim 1, wherein:

the XML format file generated in C) includes geographic information relating to the work site and/or dig area specified in the locate request ticket; and

in D), the historical information is selected based at least in part on the geographic information relating to the work site and/or dig area specified in the locate request ticket.

13. The apparatus of claim 12, wherein:

the historical information includes the historical damage reports;

in D), the at least one processor performs the statistical analysis of the historical damage reports to determine at least one distance between a first location of the work site and/or dig area as indicated by the geographic information specified in the locate request ticket and a second location of at least one previous accident indicated in the historical damage reports; and

in E), the at least one processor automatically assigns the at least one risk designation to the locate request ticket based at least in part on the at least one distance determined in D).

14. The apparatus of claim 13, wherein:

the historical damage reports include at least one damage cost associated with the at least one previous accident; and

in E), the at least one processor automatically assigns the at least one risk designation to the locate request ticket based at least in part on the at least one distance determined in D) and the at least one damage cost associated with the at least one previous accident.

15. The apparatus of any one of claims 12, wherein:

the historical information includes the historical records of previously completed locate request tickets; and
in D), at least one of the historical records of previously completed locate request tickets is selected based at least in part on a proximity between a first location of the work site and/or dig area as indicated by the geographic information specified in the locate request ticket and a second location of a historical work site and/or dig area specified by the at least one of the historical records of previously completed locate request tickets.

16. The apparatus of claim 15, wherein:

the at least one of the historical records of previously completed locate request tickets relates to a high profile ticket;

in D), the at least one processor performs the statistical analysis of the at least one of the historical records to determine at least one distance between the first location of the work site and/or dig area as indicated by the geographic information specified in the locate request ticket and the second location of the high profile ticket; and

in E), the at least one processor automatically assigns the at least one risk designation to the locate request ticket based at least in part on the at least one distance determined in D).

17. An apparatus for providing a resource to complete a locate and/or marking operation, the apparatus comprising:

at least one communication interface;

at least one memory to store processor-executable instructions; and

at least one processor communicatively coupled to the at least one memory and the at least one communication interface, wherein execution of the processor-executable instructions by the at least one processor, the at least one processor:

A) controls the at least one communication interface so as to receive a locate request ticket generated by a one-call center to specify the locate and/or marking operation, the locate and/or marking operation comprising detecting and/or marking a presence or an absence of at least one underground facility within a dig area at a work site, wherein at least a portion of the dig area is planned to be excavated or disturbed during excavation activities at the work site;

B) parses the locate request ticket received in A) so as to extract ticket information obtained from the locate request ticket;

C) generates an Extensible Markup Language (XML) format file comprising the extracted ticket information, including:

a first identifier for an excavator performing the excavation activities at the work site; and

a second identifier for the work site and/or the dig area;

D) assigns at least one risk designation to the locate request ticket based at least in part on historical information, the historical information including:

an excavator damage history for the excavator identified by the first identifier;

historical damage reports for at least one damage location in proximity to the work site and/or the dig area identified by the second identifier; and

historical records of previously completed locate request tickets for a geographic area encompassing and/or proximate to the work site and/or the dig area identified by the second identifier, and/or including excavator information relating to the excavator identified by the first identifier; and

E) controls the at least one communication interface to transmit, and/or controls the at least one memory to store, the at least one risk designation so as to facilitate clearing the locate request ticket and/or dispatching at least one locate technician to perform the locate and/or marking operation, based at least in part on the at least one risk designation assigned in D).

18. In a system comprising at least one processor, at least one memory, and at least one communication interface, a method for providing a resource to complete a locate and/or marking operation, the method comprising:

A) receiving, via the at least one communication interface, a locate request ticket generated by a one-call center to specify the locate and/or marking operation, the locate and/or marking operation comprising detecting and/or marking a presence or an absence of at least one underground facility within a dig area at a work site, wherein at least a portion of the dig area is planned to be excavated or disturbed during excavation activities at the work site;

B) parsing, via the at least one processor, the locate request ticket received in A) so as to extract ticket information obtained from the locate request ticket;

C) generating, via the at least one processor, an Extensible Markup Language (XML) format file comprising the extracted ticket information;

D) performing, via the at least one processor, a statistical analysis of historical information, the historical information being selected based at least in part on the XML format file generated in C) and including at least one of:

historical damage reports for underground facility infrastructure; and

historical records of previously completed locate request tickets;

E) automatically assigning, via the at least one processor, at least one risk designation to the locate request ticket based at least in part on the statistical analysis of the historical information performed in D); and

F) transmitting via the at least one communication interface, and/or storing in the at least one memory, the at least one risk designation so as to facilitate clearing the locate request ticket and/or dispatching at least one locate technician to perform the locate and/or marking operation, based at least in part on the at least one risk designation automatically assigned in E).

19. At least one non-transitory computer-readable storage medium encoded with at least one program including processor-executable instructions that, when executed by a processor, performs a method for providing a resource to complete a locate and/or marking operation, the method comprising:

A) receiving a locate request ticket generated by a one-call center to specify the locate and/or marking operation, the locate and/or marking operation comprising detecting and/or marking a presence or an absence of at least one underground facility within a dig area at a work site, wherein at least a portion of the dig area is planned to be excavated or disturbed during excavation activities at the work site;

B) parsing the locate request ticket received in A) so as to extract ticket information obtained from the locate request ticket;

C) generating an Extensible Markup Language (XML) format file comprising the extracted ticket information;
D) performing a statistical analysis of historical information, the historical information being selected based at least in part on the XML format file generated in C) and including at least one of: historical damage reports for underground facility infrastructure; and historical records of previously completed locate request tickets;
E) automatically assigning at least one risk designation to the locate request ticket based at least in part on the statistical analysis of the historical information performed in D); and
F) transmitting via the at least one communication interface, and/or storing in the at least one memory, the at least one risk designation so as to facilitate clearing the locate request ticket and/or dispatching at least one locate technician to perform the locate and/or marking operation, based at least in part on the at least one risk designation automatically assigned in E).
20. The computer-readable storage medium of claim 19, wherein the at least one risk designation comprises a numerical score.
21. The computer-readable storage medium of claim 19, wherein:
the XML format file generated in C) includes type information relating to at least one type of underground facility specified in the locate request ticket; and
in D), the historical information is selected for statistical analysis based at least in part on the type information relating to the at least one type of underground facility specified in the locate request ticket.
22. The computer-readable storage medium of claim 21, wherein:
the historical information includes the historical damage reports;
in D), the statistical analysis of the historical damage reports is performed to determine a frequency of damages relating to the at least one type of underground facility and/or a damage cost associated with the at least one type of underground facility; and
in E), the at least one risk designation is automatically assigned to the locate request ticket based at least in part on the frequency of damages relating to the at least one type of underground facility and/or the damage cost associated with the at least one type of underground facility.
23. The computer-readable storage medium of claim 19, wherein:
the XML format file generated in C) includes excavator information relating to at least one excavator specified in the locate request ticket; and
in D), the historical information is selected based at least in part on the excavator information relating to the at least one excavator specified in the locate request ticket.
24. The computer-readable storage medium of claim 23, wherein:
the historical information includes the historical damage reports;
the historical damage reports include an excavator damage history for the at least one excavator specified in the locate request ticket;
the excavator damage history includes excavator damage costs and/or excavator damage counts; and
in E), the at least one risk designation is automatically assigned to the locate request ticket based at least in part on the excavator damage costs and/or excavator damage counts.
25. The computer-readable storage medium of claim 19, wherein:
the XML format file generated in C) includes geographic information relating to the work site and/or dig area specified in the locate request ticket; and
in D), the historical information is selected based at least in part on the geographic information relating to the work site and/or dig area specified in the locate request ticket.
26. The computer-readable storage medium of claim 25, wherein:
the historical information includes the historical damage reports;
in D), the statistical analysis of the historical damage reports is performed to determine at least one distance between a first location of the work site and/or dig area as indicated by the geographic information specified in the locate request ticket and a second location of at least one previous accident indicated in the historical damage reports; and
in E), the at least one risk designation is automatically assigned to the locate request ticket based at least in part on the at least one distance determined in D).
27. The computer-readable storage medium of claim 26, wherein:
the historical damage reports include at least one damage cost associated with the at least one previous accident; and
in E), the at least one risk designation is automatically assigned to the locate request ticket based at least in part on the at least one damage cost associated with the at least one previous accident.
28. The computer-readable storage medium of claim 25, wherein:
the historical information includes the historical records of previously completed locate request tickets; and
in D), at least one of the historical records of previously completed locate request tickets is selected based at least in part on a proximity between a first location of the work site and/or dig area as indicated by the geographic information specified in the locate request ticket and a second location of a historical work site and/or dig area specified by the at least one of the historical records of previously completed locate request tickets.
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